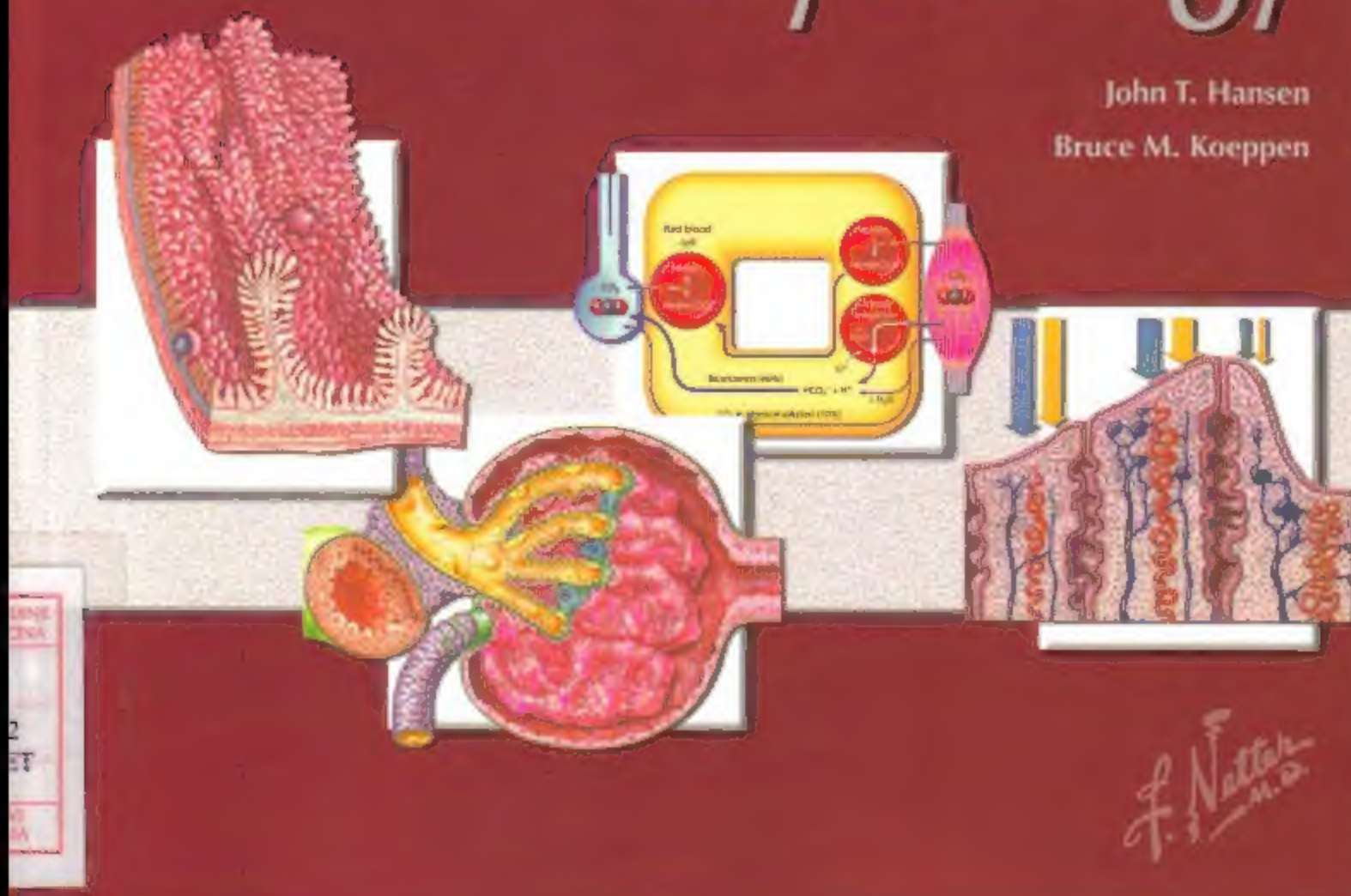


Netter's Atlas of Human Physiology

John T. Hansen
Bruce M. Koeppen



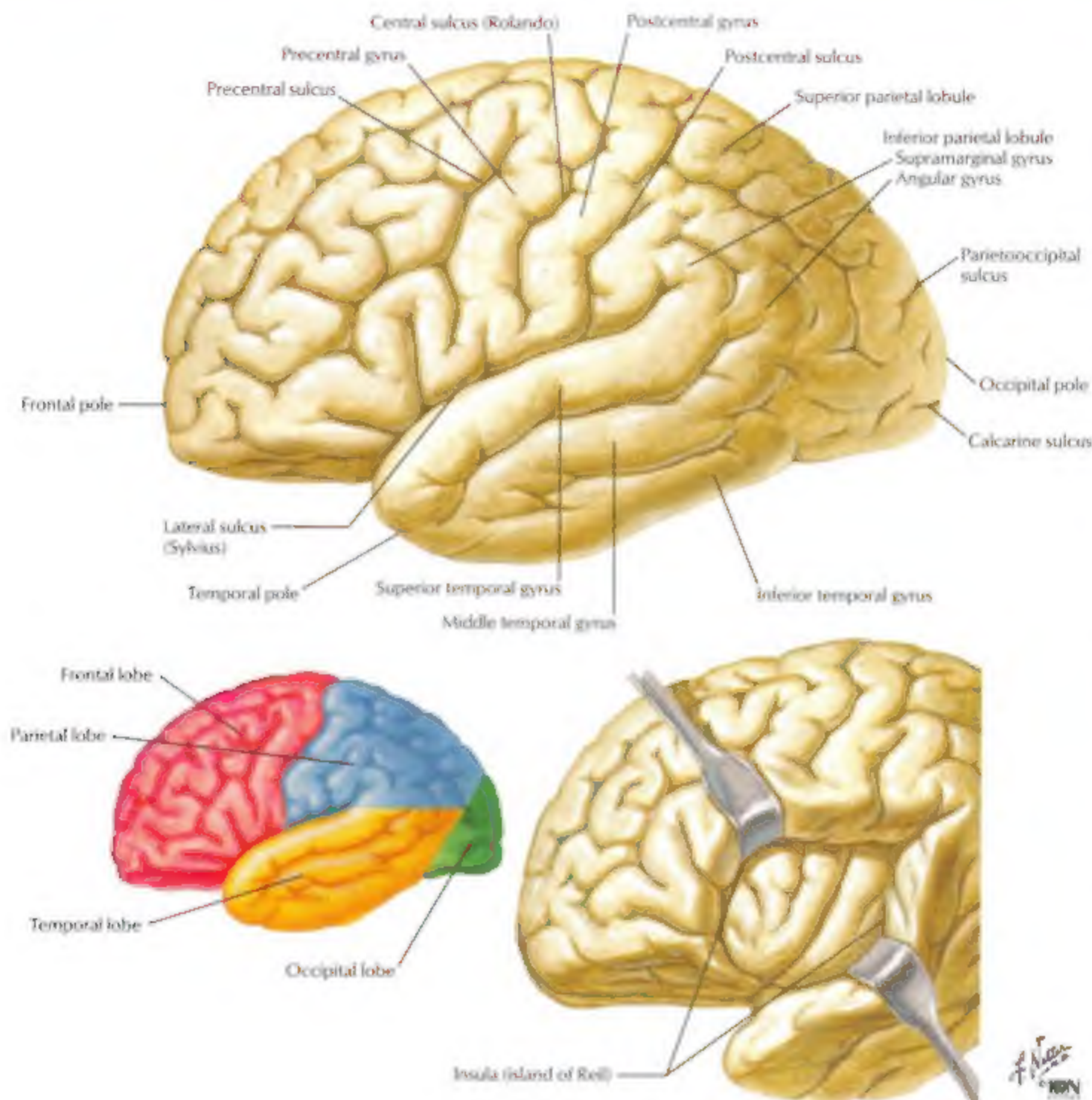


FIGURE 2.1 ORGANIZATION OF THE BRAIN: CEREBRUM

The cerebral cortex represents the highest center for sensory and motor processing. In general, the frontal lobe processes motor, visual, speech, and personality modalities. The parietal lobe processes sensory information; the temporal lobe, auditory and memory modalities; and the occipital lobe, vision. The cerebellum coordinates smooth

motor activities and processes muscle position. The brainstem (medulla, pons, midbrain) conveys motor and sensory information and mediates important autonomic functions. The spinal cord receives sensory input from the body and conveys somatic and autonomic motor information to peripheral targets (muscles, viscera).

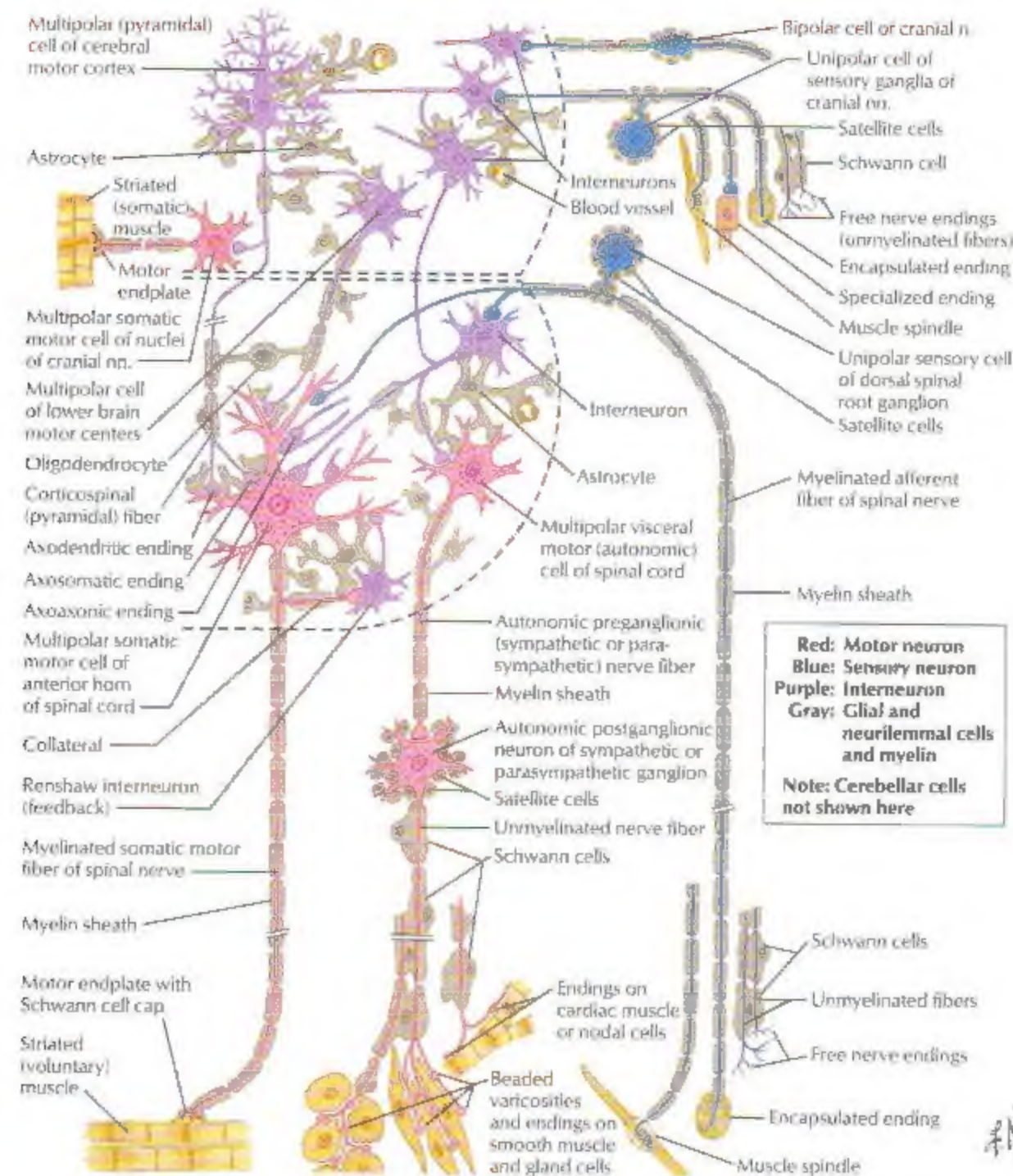


FIGURE 2.2 ORGANIZATION OF THE BRAIN: CELL TYPES

Neurons form the functional cellular units responsible for communication, and throughout the nervous system, they are characterized by their distinctive size and shapes (e.g., bipolar, unipolar, multipolar). Supporting cells include the neuroglia (e.g.,

astrocytes, oligodendrocytes), satellite cells, and other specialized cells that optimize neuronal function, provide maintenance functions, or protect the nervous system.

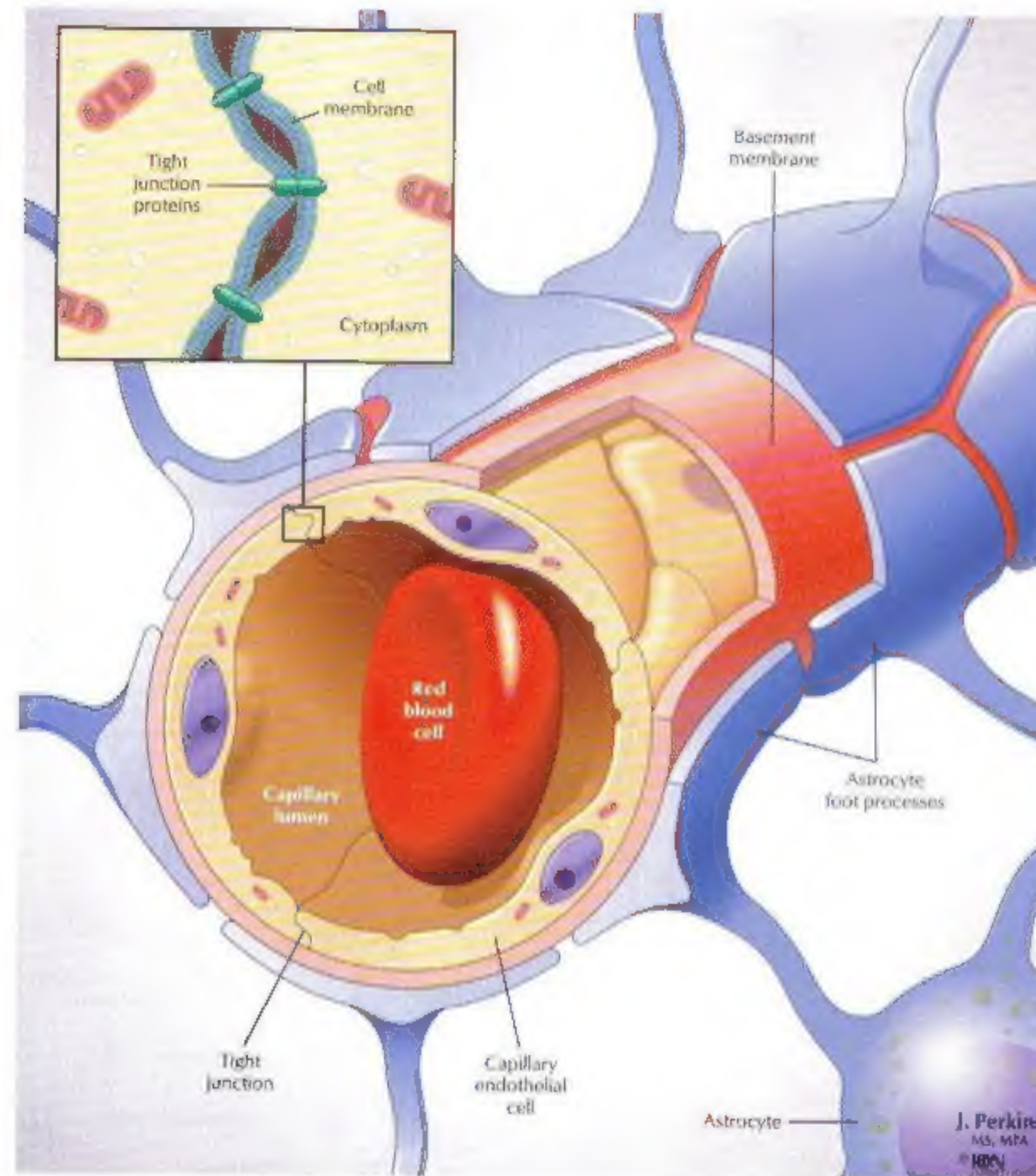


FIGURE 2.3 BLOOD-BRAIN BARRIER

The blood-brain barrier (BBB) is the cellular interface between the blood and the central nervous system (CNS: brain and spinal cord). It serves to maintain the interstitial fluid environment to ensure optimal functionality of the neurons. This barrier consists of the capillary endothelial cells with an elaborate network of tight junctions and astrocytic foot processes that abut the endothelium and its basement membrane. The movement of large molecules and

other substances (including many drugs) from the blood to the interstitial space of the CNS is restricted by the BBB. CNS endothelial cells also exhibit a low level of pinocytotic activity across the cell, so specific carrier systems for the transport of essential substrates of energy and amino acid metabolism are characteristic of these cells. The astrocytes help transfer important metabolites from the blood to the neurons and also remove excess K^+ and neurotransmitters from the interstitial fluid.

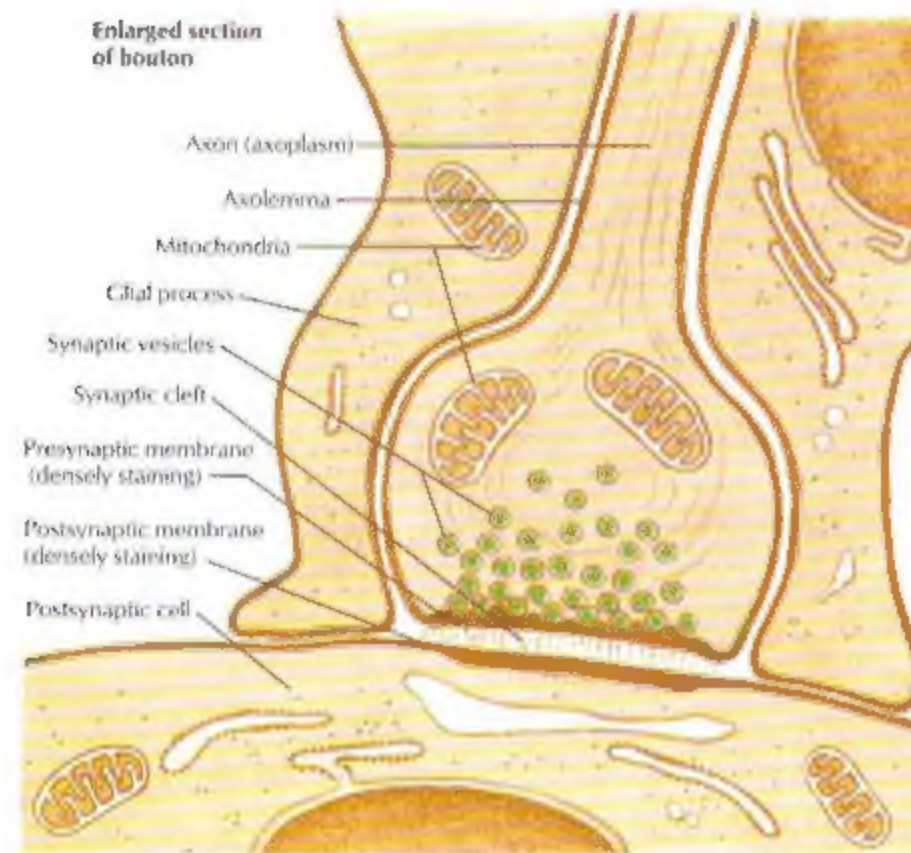
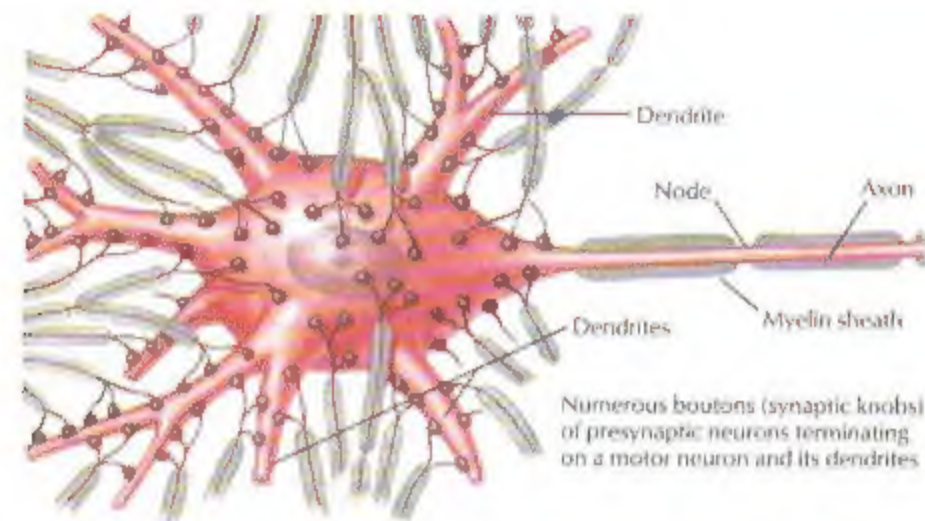


FIGURE 2.4 MORPHOLOGY OF SYNAPSES

Neurons communicate with each other and with effector targets at specialized regions called synapses. The top figure shows a typical motor neuron that receives numerous synaptic contacts on its cell body and associated dendrites. Incoming axons lose their myelin sheaths, exhibit extensive branching, and terminate as synaptic boutons (synaptic terminals or knobs) on the motor neuron. The lower

figure shows an enlargement of one such synaptic bouton. Chemical neurotransmitters are contained in synaptic vesicles, which can fuse with the presynaptic membrane, release the transmitters into the synaptic cleft, and then bind to receptors situated in the postsynaptic membrane. This synaptic transmission results in excitatory, inhibitory, or modulatory effects on the target cell.

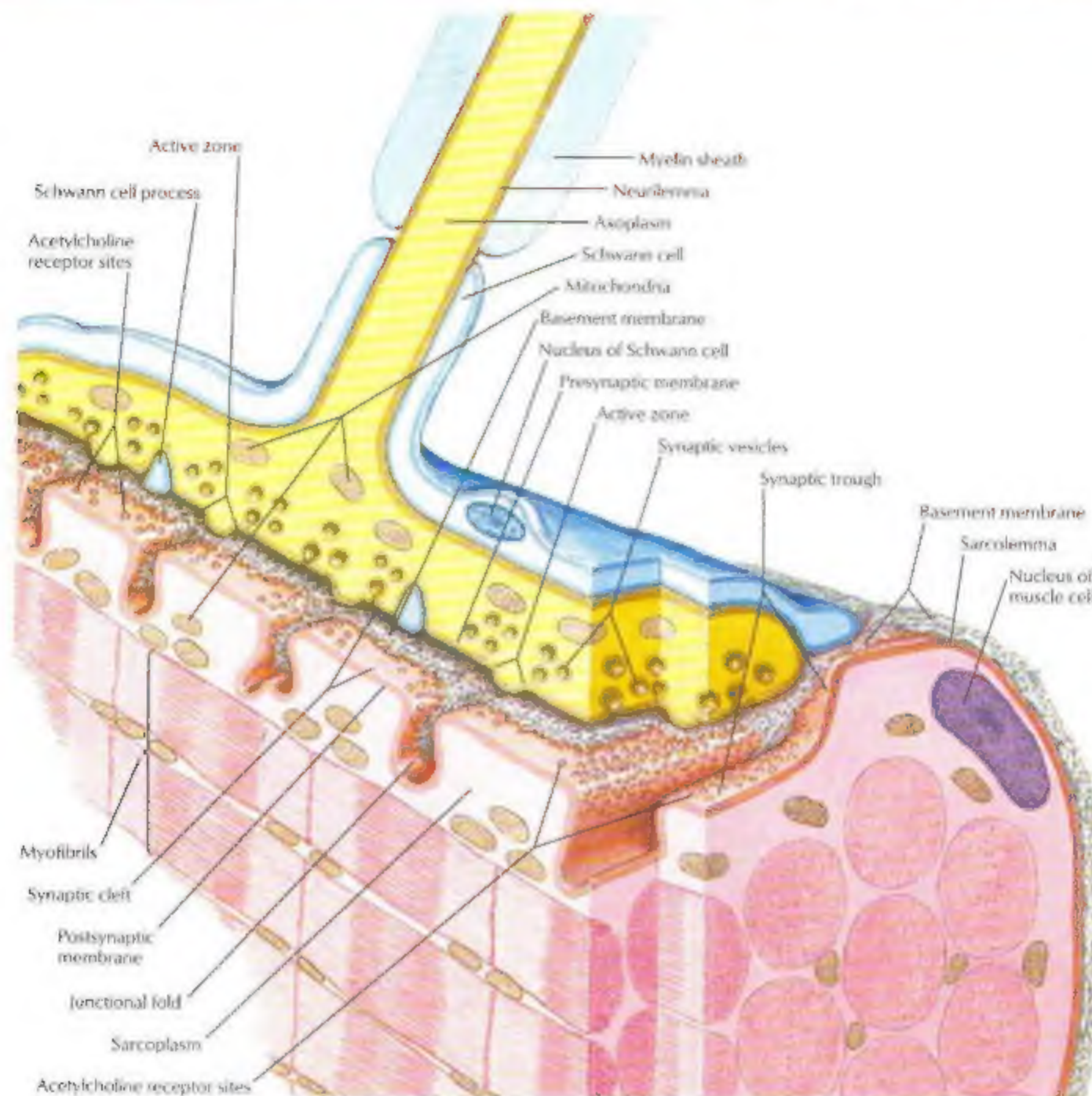


FIGURE 2.5 STRUCTURE OF THE NEUROMUSCULAR JUNCTION

Motor axons that synapse on skeletal muscle form expanded terminals called neuromuscular junctions (motor endplates). The motor axon loses its myelin sheath and expands into a Schwann cell-invested synaptic terminal that resides within a trough in the muscle fiber. Acetylcholine-containing synaptic vesicles accumulate adjacent to the presynaptic membrane and, when appropriately stim-

ulated, release their neurotransmitter into the synaptic cleft. The transmitter then binds to receptors that mediate depolarization of the muscle sarcolemma and initiate a muscle action potential. A single muscle fiber has only one neuromuscular junction, but a motor axon can innervate multiple muscle fibers.

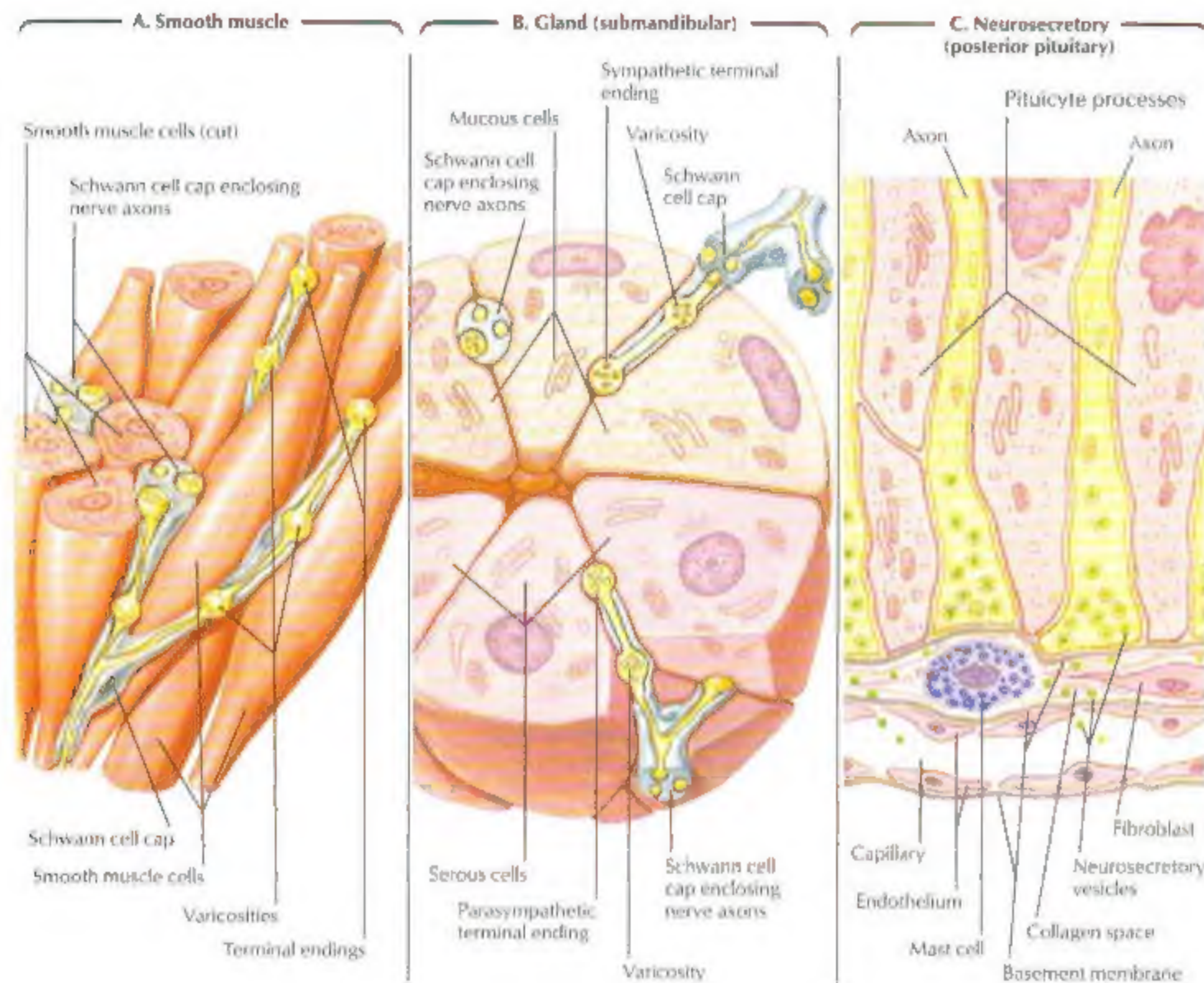


FIGURE 2.6 VISCERAL EFFERENT ENDINGS

Neuronal efferent endings on smooth muscle (A) and glands (B and C) exhibit unique endings unlike the presynaptic and postsynaptic terminals observed in neuronal and neuromuscular junction synapses. Rather, neurotransmitter substances are released into interstitial spaces (A and B) or into the bloodstream (C, neurosecre-

tion) from expanded nerve terminal endings. This arrangement allows for the stimulation of numerous target cells over a wide area. Not all smooth muscle cells are innervated. They are connected to adjacent cells by gap junctions and can therefore contract together with the innervated cells.

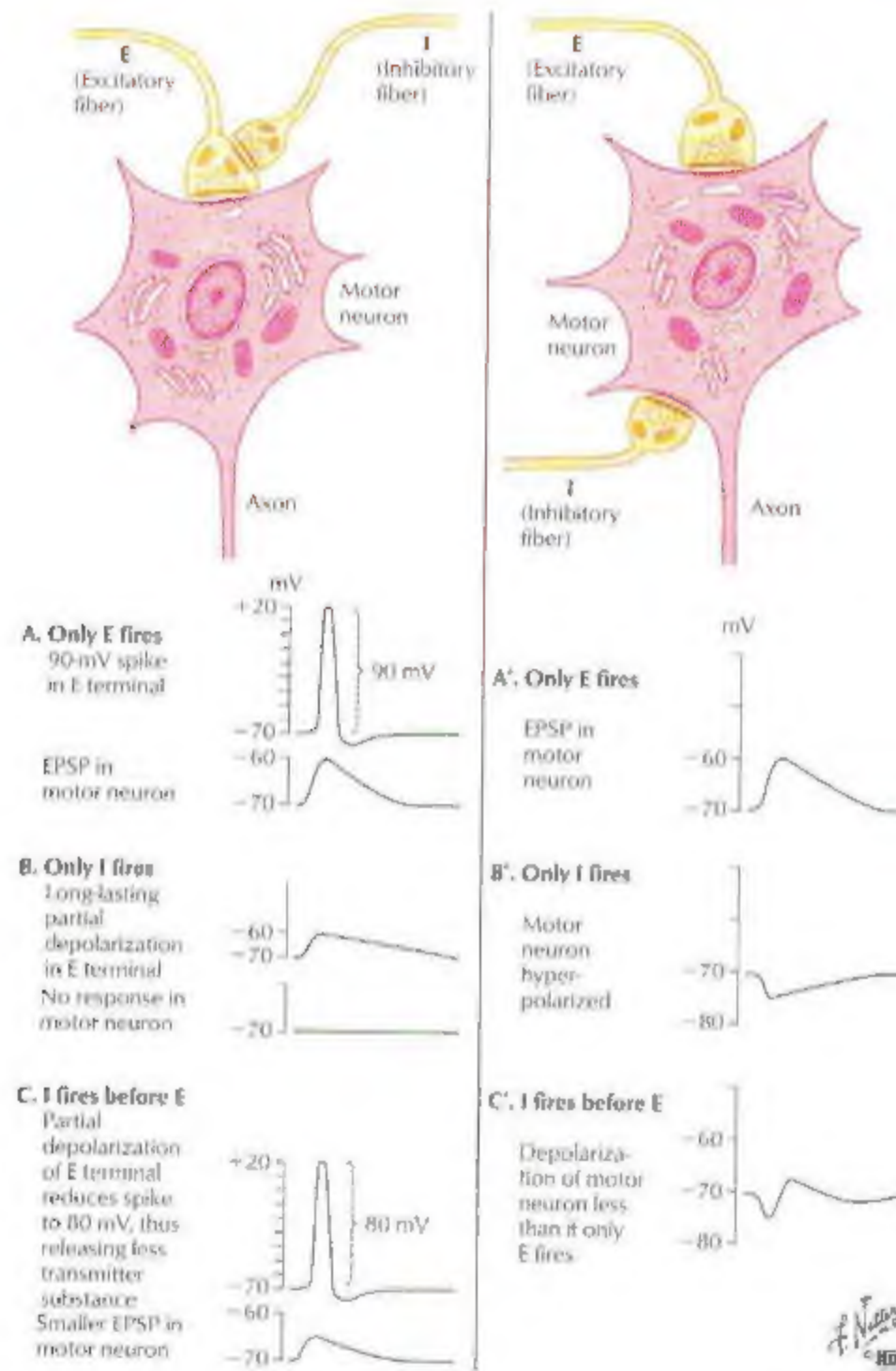


FIGURE 2.7 SYNAPTIC INHIBITORY MECHANISMS

Inhibitory synapses modulate neuronal activity. Illustrated here is presynaptic inhibition (left panel) and postsynaptic inhibition (right panel) at a motor neuron.

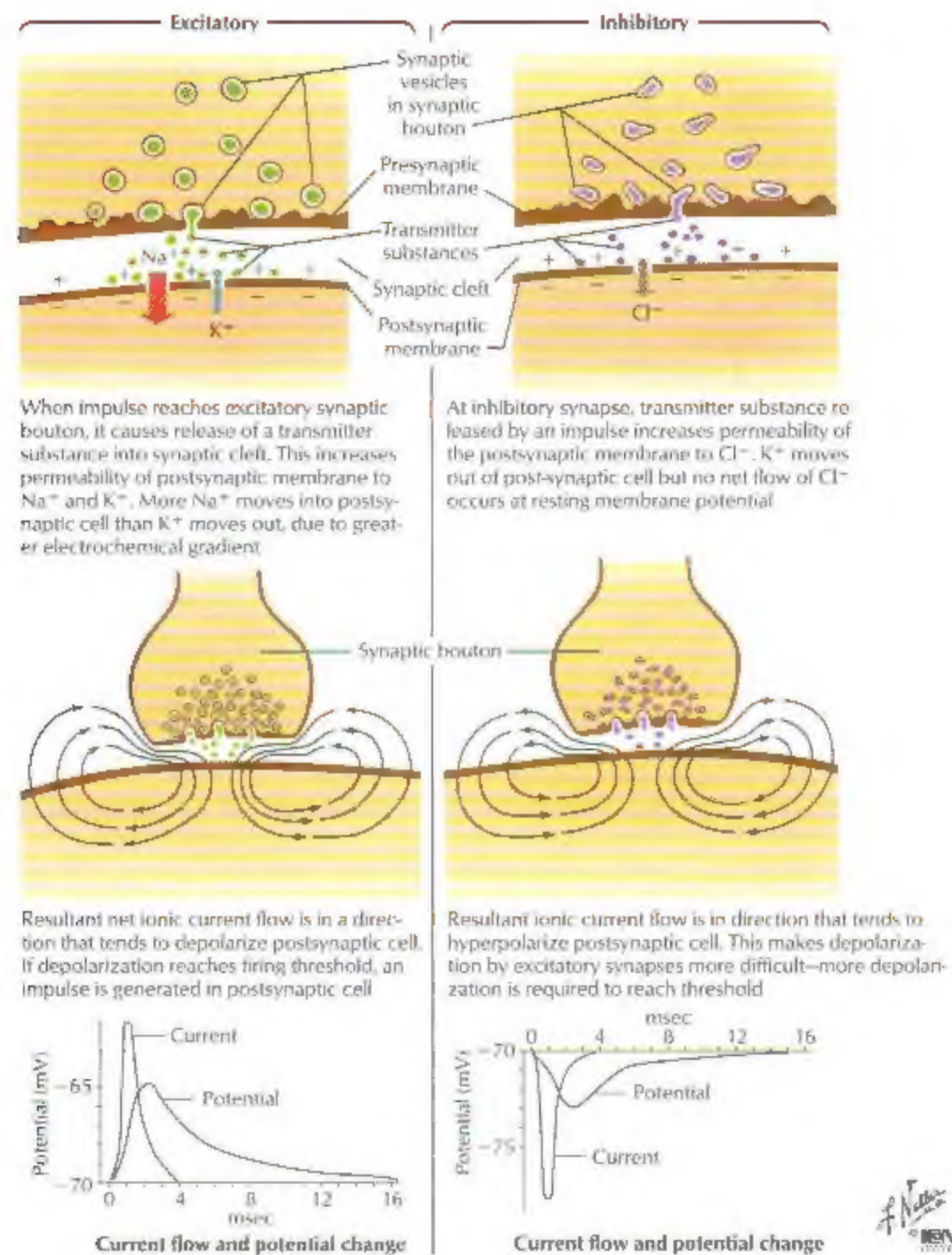


FIGURE 2.8 CHEMICAL SYNAPTIC TRANSMISSION

Chemical synaptic transmission between neurons may be excitatory or inhibitory. During excitation (left column), a net increase in the inward flow of Na^+ compared with the outward flow of K^+ results in a depolarizing potential change (excitatory postsynaptic potential [EPSP]) that drives the postsynaptic cell closer to its threshold for an

action potential. During inhibition (right column), the opening of K^+ and Cl^- channels drives the membrane potential away from threshold (hyperpolarization) and decreases the probability that the neuron will reach threshold (inhibitory postsynaptic potential [IPSP]) for an action potential.

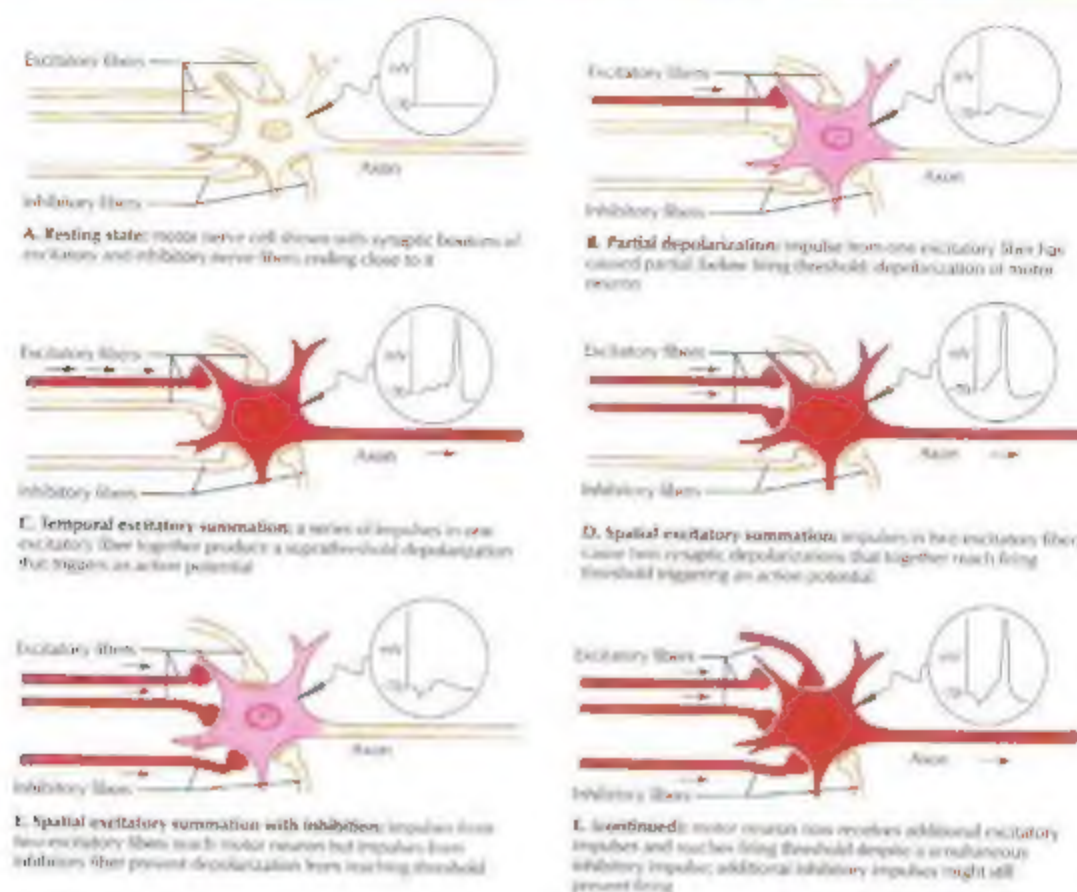


CHART 2.1 SUMMARY OF SOME NEUROTRANSMITTERS AND WHERE WITHIN THE CENTRAL AND PERIPHERAL NERVOUS SYSTEM THEY ARE FOUND

Transmitter	Location	Transmitter	Location
Acetylcholine	Neuromuscular junction, autonomic endings and ganglia, CNS	Gas	
Bioactive amines		Nitric oxide	CNS, GI tract
Norepinephrine	Sympathetic endings, CNS	Peptides	
Dopamine	CNS	β -Endorphins	CNS, GI tract
Serotonin	CNS, GI tract	Enkephalins	CNS
Amino acids		Antidiuretic hormone	CNS (hypothalamus/posterior pituitary)
γ -Aminobutyric acid (GABA)	CNS	Pituitary-releasing hormones	CNS (hypothalamus/anterior pituitary)
Glutamate	CNS	Somatostatin	CNS, GI tract
Purines		Neuropeptide Y	CNS
Adenosine	CNS	Vasoactive intestinal peptide	CNS, GI tract
Adenosine triphosphate (ATP)	CNS		

CNS, Central nervous system; GI, gastrointestinal.

FIGURE 2.9 TEMPORAL AND SPATIAL SUMMATION

Neurons receive multiple excitatory and inhibitory inputs. Temporal summation occurs when a series of subthreshold impulses in one excitatory fiber produces an action potential in the postsynaptic cell (panel C). Spatial summation occurs when subthreshold impulses from two or more different fibers trigger an action potential (panel

D). Both temporal and spatial summation can be modulated by simultaneous inhibitory input (panel E). Inhibitory and excitatory neurons use a wide variety of neurotransmitters, some of which are summarized here.

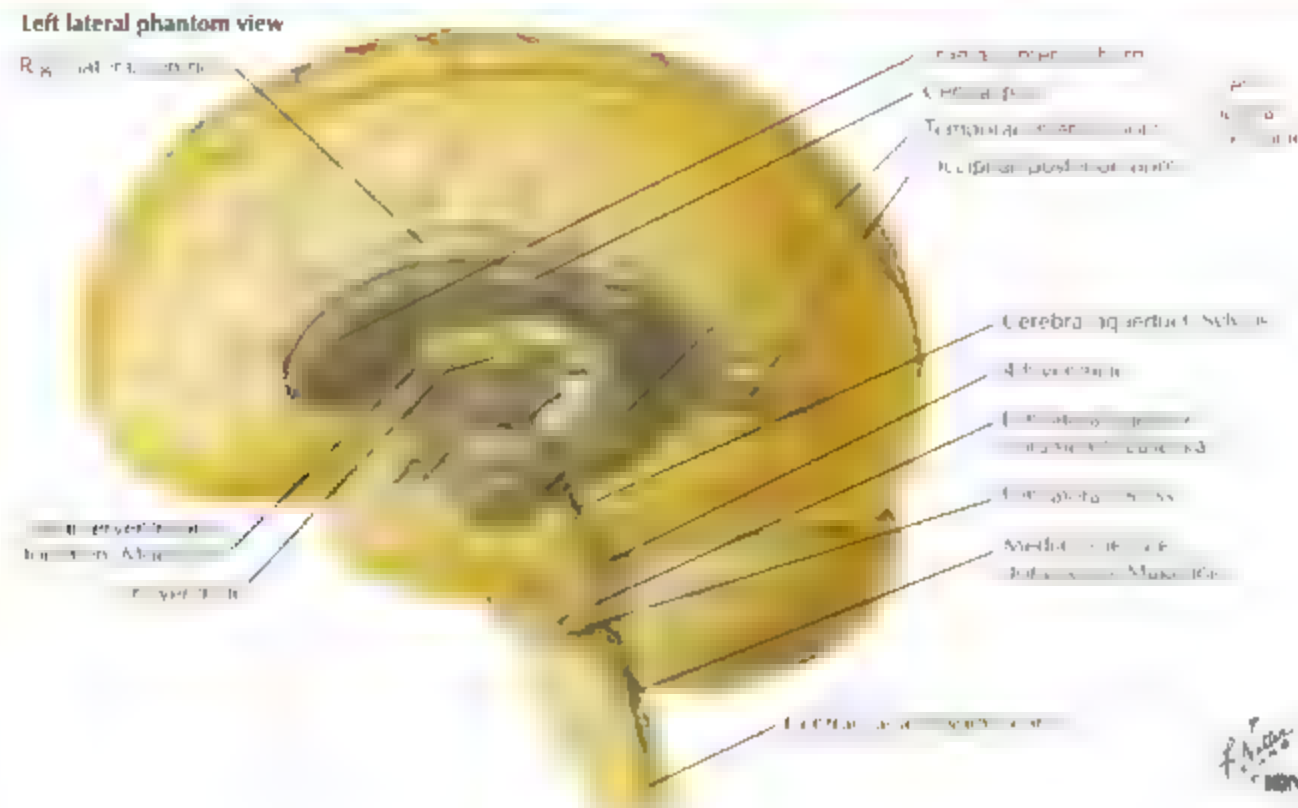


CHART 2.2 CSF COMPOSITION

	CSF	Blood
Na ⁺ (mEq/L)	154	142
K ⁺ (mEq/L)	2.5	4
Ca ²⁺ (mEq/L)	1.5	1.2
Mg ²⁺ (mEq/L)	1.5	1.2
Glucose (mg/dL)	50	100
Protein (mg/dL)	15	7
pH	7.3	7.4

FIGURE 2.10 BRAIN VENTRICLES AND CSF COMPOSITION

CSF circulates through the four brain ventricles, two lateral ventricles and the third and fourth ventricles, the subarachnoid space surrounding the brain and spinal cord. The blood vessels in the brain and spinal cord are surrounded by CSF, which is regulated by the blood-brain barrier.

Importantly, the blood-brain barrier (BBB) is a plasma membrane that separates the blood from the brain tissue. This allows for changes in blood pH to cause changes in CSF pH, which in turn regulates the pH of the brain tissue.

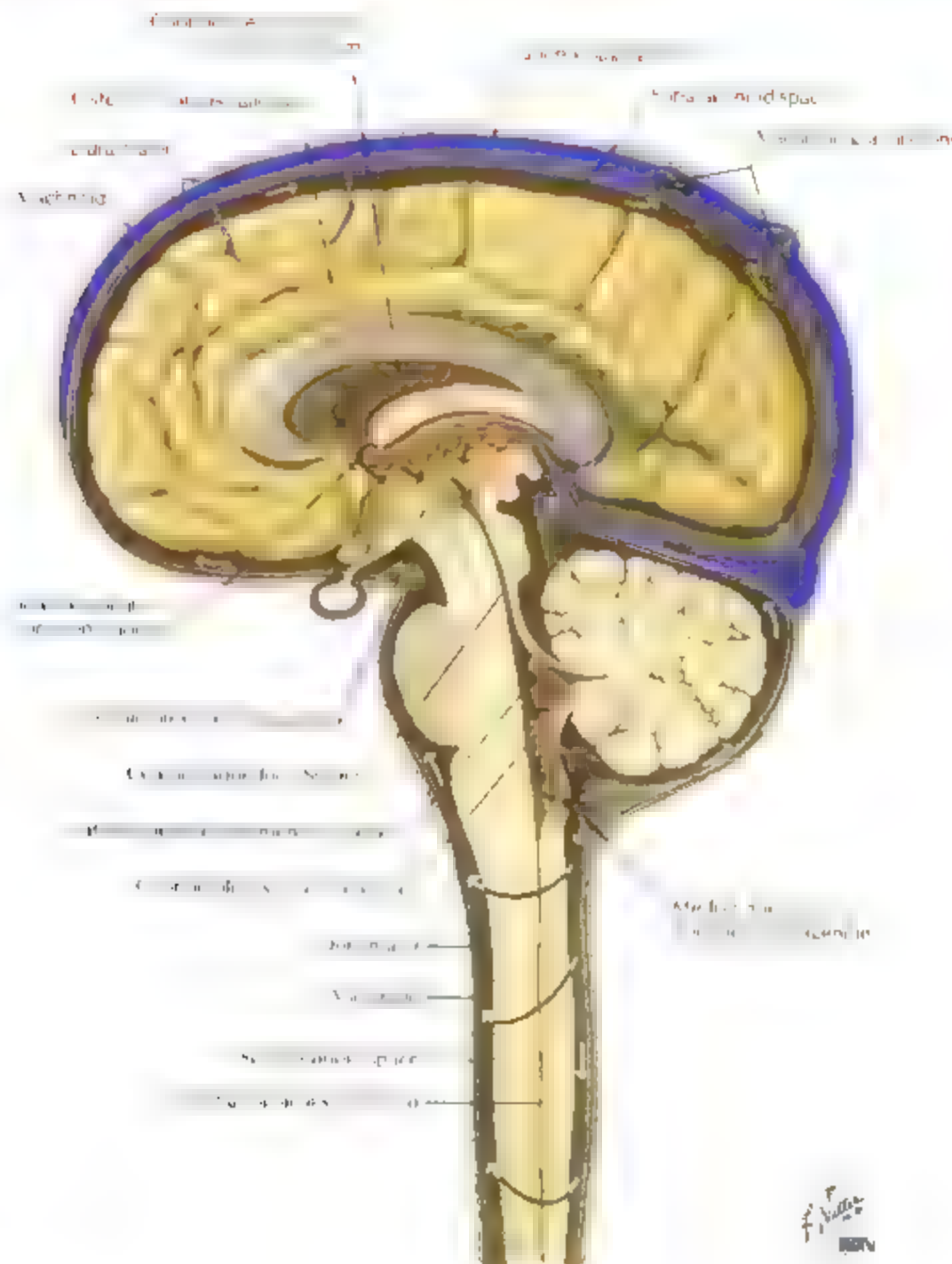


FIGURE 2.11 CIRCULATION OF CEREBROSPINAL FLUID

CSF circulates through the ventricular system and the subarachnoid space. It is produced in the lateral ventricles and flows through the interventricular foramina into the third ventricle. From the third ventricle, it flows through the cerebral aqueduct into the fourth ventricle. From the fourth ventricle, it flows into the subarachnoid space, which surrounds the brain and spinal cord. The central canal of the spinal cord is continuous with the fourth ventricle.

After the CSF has circulated through the subarachnoid space, it is absorbed into the venous system through the arachnoid villi. The CSF is then reabsorbed into the venous system through the arachnoid villi. The CSF is then reabsorbed into the venous system through the arachnoid villi.



of these systems includes the skeletal system, muscles, and sensory organs. Every organism has the following systems in its body: skin, skeletal muscles, and joints.

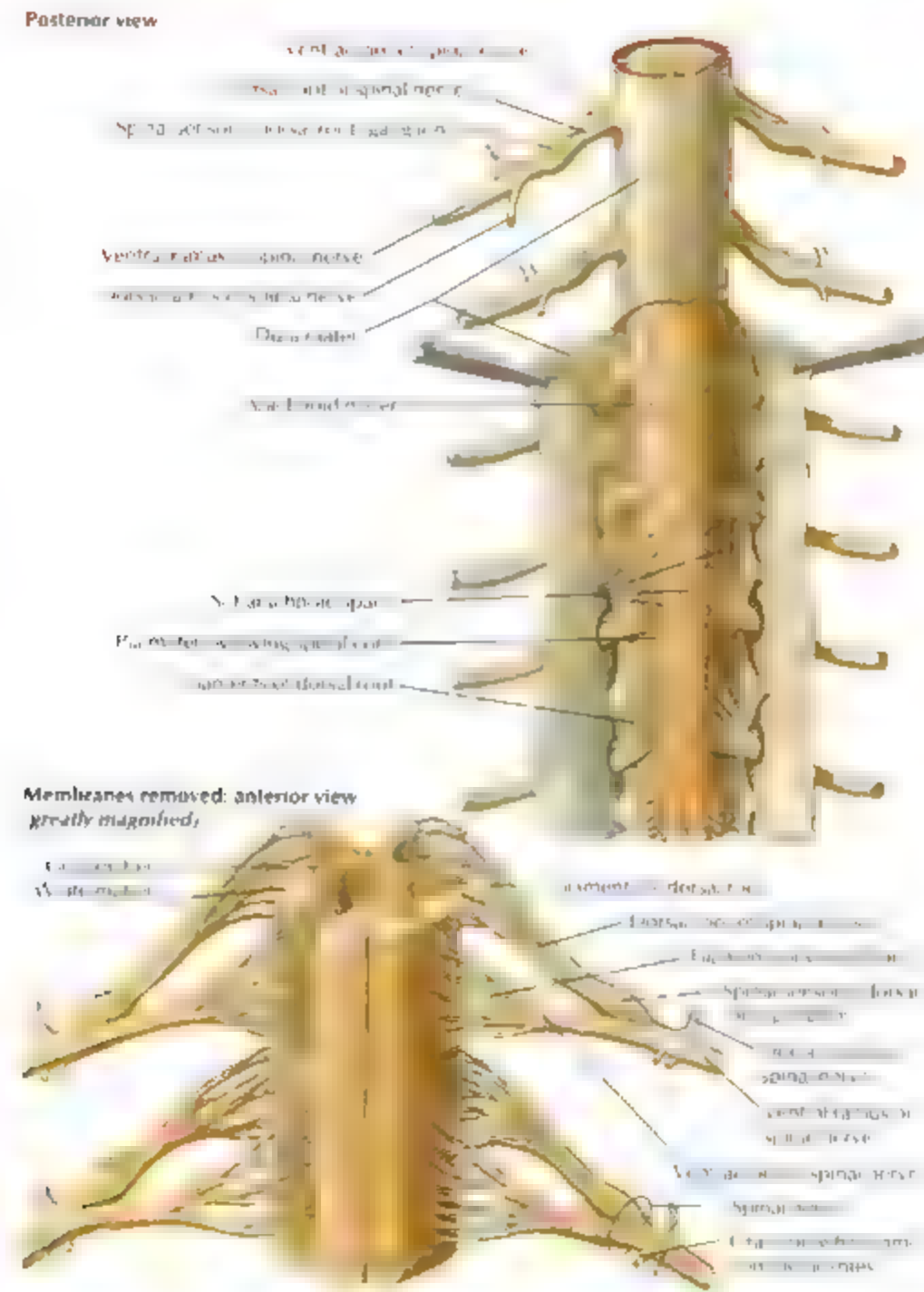


FIGURE 2.13 SPINAL MEMBRANES AND NERVE ROOTS

The spinal cord gives rise to 31 pairs of peripheral nerves that distribute segmentally to the body. Most of the spinal nerves are composed of axons from the ventral and dorsal roots. The ventral root carries axons from the ventral horn of the spinal cord, and the dorsal root carries axons from the dorsal root ganglion.

The spinal cord is enclosed by three meningeal layers: the outermost layer is the dura mater, the middle layer is the arachnoid mater, and the innermost layer is the pia mater. The spinal cord is also surrounded by cerebrospinal fluid (CSF) in the subarachnoid space.

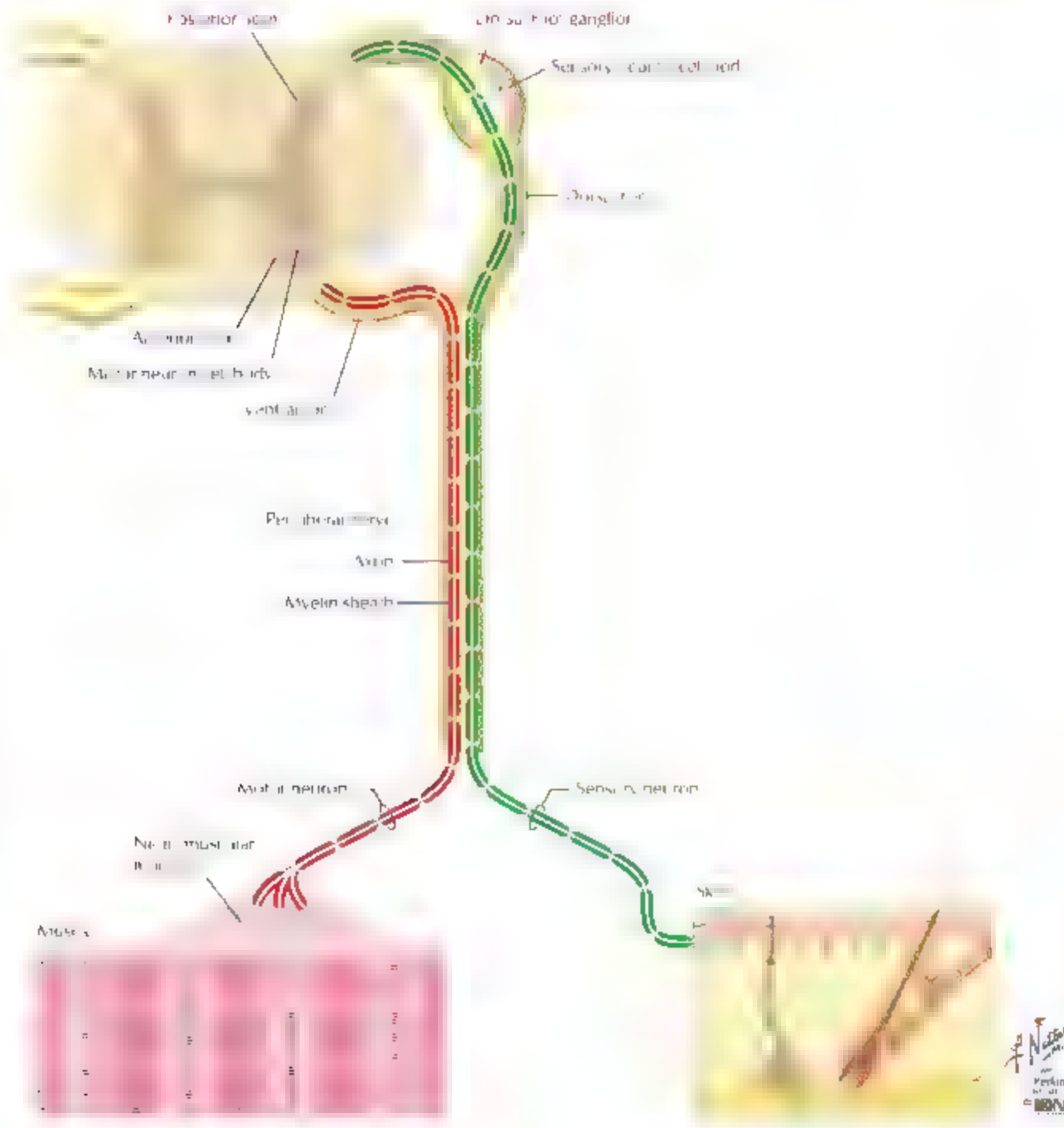


FIGURE 2.14 PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system (PNS) consists of all the neural elements outside of the CNS (brain and spinal cord) and provides the connections between the CNS and all other body components. The PNS consists of somatic and autonomic components. The somatic component innervates skeletal muscle and skin and is

shown here (see Figure 2.14). The autonomic component is shown in the somatic component of the peripheral nerves contains both motor and sensory axons (cell bodies of the motor neurons are found in the anterior horn of the spinal cord, whereas the cell bodies of sensory neurons are located in the dorsal root ganglia).

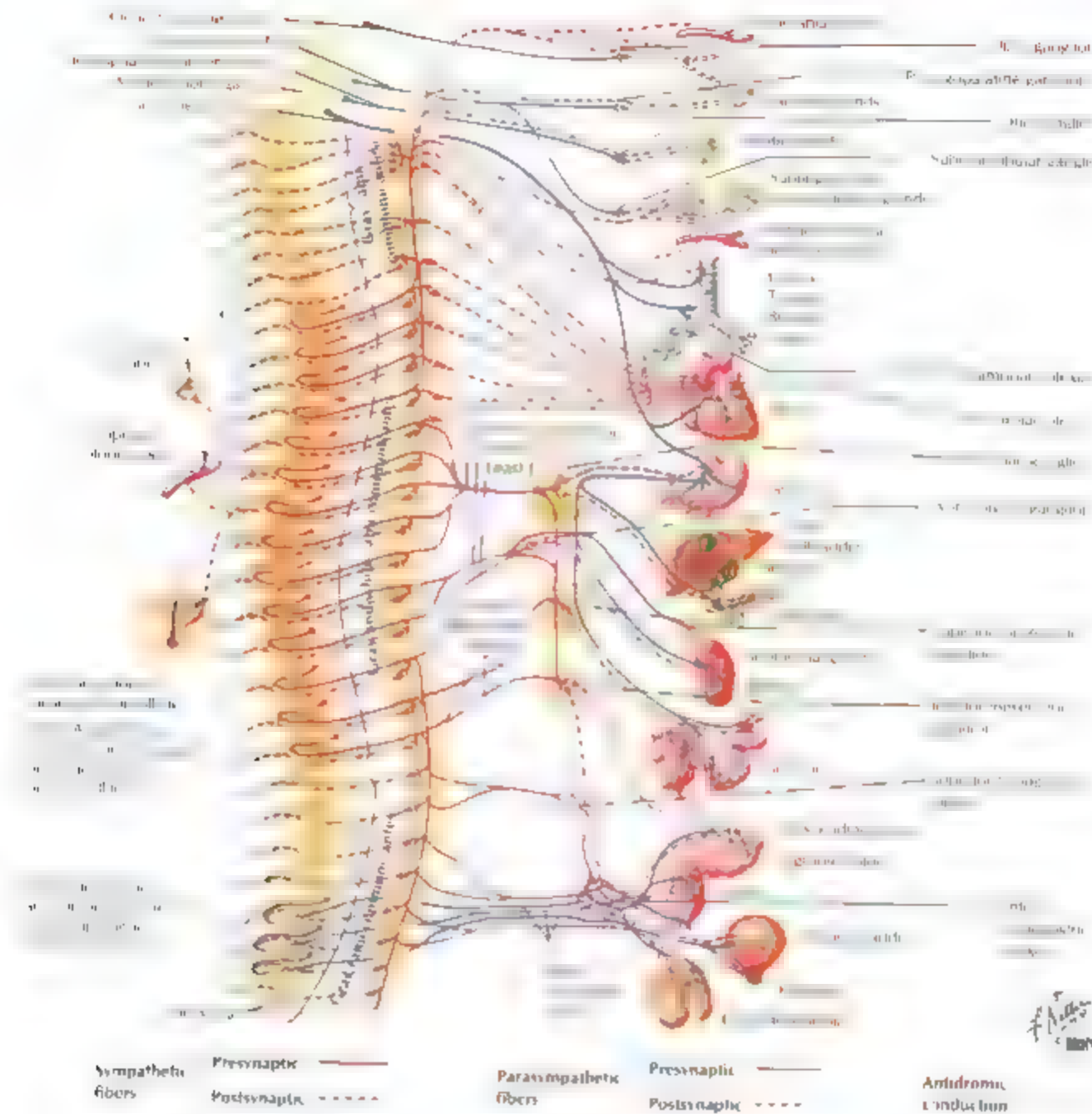


FIGURE 2.15 AUTONOMIC NERVOUS SYSTEM SCHEMA

The autonomic nervous system (ANS) is a complex system that controls the body's internal organs and functions. It is divided into two main branches: the sympathetic system and the parasympathetic system. The sympathetic system is responsible for the 'fight or flight' response, while the parasympathetic system is responsible for the 'rest and digest' response. The ANS is controlled by the brain and the spinal cord. The sympathetic system originates in the thoracic and lumbar regions of the spinal cord, while the parasympathetic system originates in the brainstem and the sacral region of the spinal cord. The ANS controls a wide range of functions, including heart rate, blood pressure, digestion, and reproduction.

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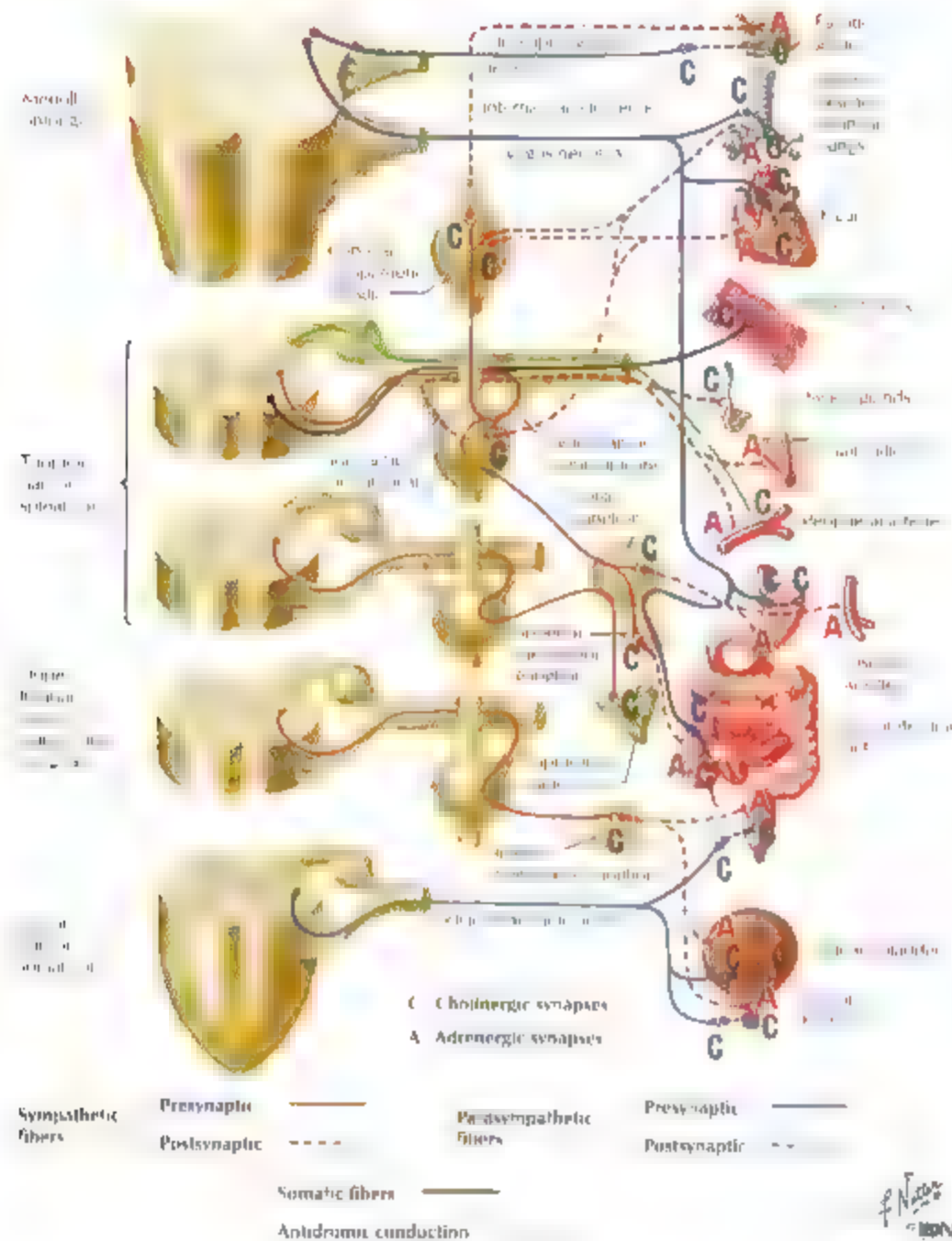


FIGURE 2.16 CHOLINERGIC AND ADRENERGIC SYNAPSES: SCHEMA

The autonomic nervous system (ANS) is a branch of the peripheral nervous system (PNS) that controls the internal organs and glands. It is divided into the sympathetic and parasympathetic divisions. The sympathetic division is responsible for the "fight or flight" response, while the parasympathetic division is responsible for the "rest and digest" response. The ANS uses two types of synapses: cholinergic and adrenergic. Cholinergic synapses use the neurotransmitter acetylcholine (ACh), while adrenergic synapses use the neurotransmitter norepinephrine (NE). The diagram shows the pathways of these two types of synapses throughout the body.

The sympathetic division of the ANS is responsible for the "fight or flight" response. It uses adrenergic synapses to release norepinephrine (NE) into the bloodstream. NE then acts on the heart, lungs, and other organs to increase heart rate, dilate the bronchi, and increase blood pressure. The parasympathetic division of the ANS is responsible for the "rest and digest" response. It uses cholinergic synapses to release acetylcholine (ACh) into the bloodstream. ACh then acts on the heart, lungs, and other organs to decrease heart rate, constrict the bronchi, and decrease blood pressure.



CHART 2.3 MAJOR FUNCTIONS OF THE HYPOTHALAMUS

Hypothalamic Area	Major Functions*
Preoptic and anterior	Heat loss center: promotes vasodilation and sweating
Posterior	Heat conservation center: stimulates vasoconstriction and shivering
Lateral	Feeding center: eating behavior
Ventromedial	Satiety center: inhibits eating behavior
Infundibular stalk and posterior median eminence	Releasing and inhibiting hormones for the anterior pituitary
Paraventricular	ADH and oxytocin secretion
Periventricular	Releasing hormones for the anterior pituitary

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FIGURE 2.17 SCHEMATIC RECONSTRUCTION OF THE HYPOTHALAMUS

the hypothalamus, and the circadian rhythm. The hypothalamus is a small region of the brain that acts as the body's master clock, regulating the body's internal clock and the circadian rhythm. The hypothalamus also controls the body's temperature, hunger, thirst, and sleep. The circadian rhythm is a 24-hour cycle that regulates the body's internal clock and the circadian rhythm. The circadian rhythm is controlled by the hypothalamus and the pineal gland. The pineal gland is a small, pea-sized gland that produces the hormone melatonin, which helps regulate the body's internal clock and the circadian rhythm. The pineal gland is located in the brain, behind the hypothalamus. The pineal gland is also known as the "third eye" because it is believed to be the source of the human eye's light sensitivity. The pineal gland is also known as the "third eye" because it is believed to be the source of the human eye's light sensitivity. The pineal gland is also known as the "third eye" because it is believed to be the source of the human eye's light sensitivity.

The data suggest the linear system can be used to model the modulla of elongata. Input pressure and temperature are system inputs and integrates these inputs to generate a biological output.

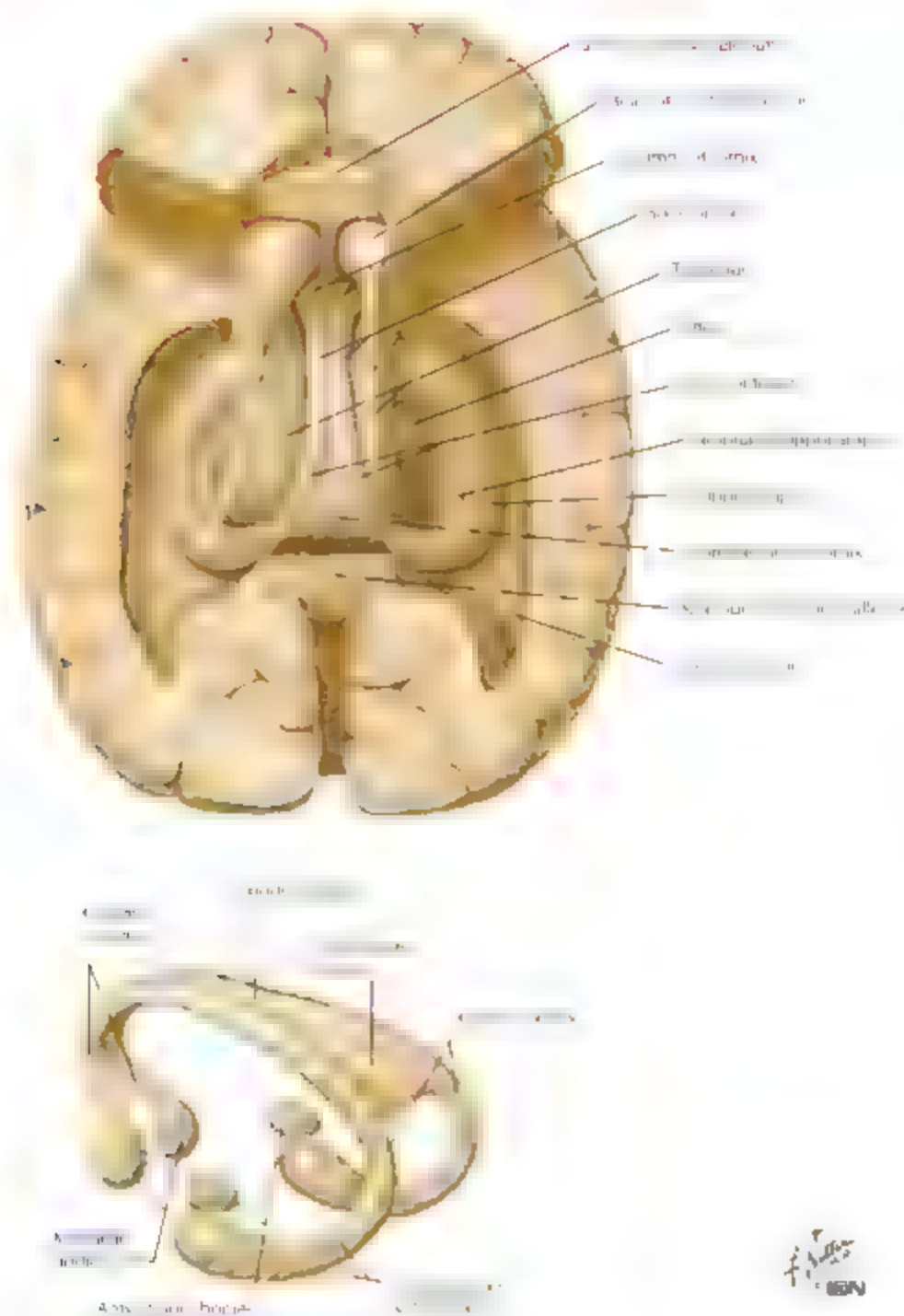


FIGURE 21B HIPPOCAMPUS AND FORNIX

The hippocampus is a structure in the limbic system that is involved in memory. It is located in the temporal lobe of the brain. The fornix is a bundle of nerve fibers that connects the hypothalamus to the hippocampus.

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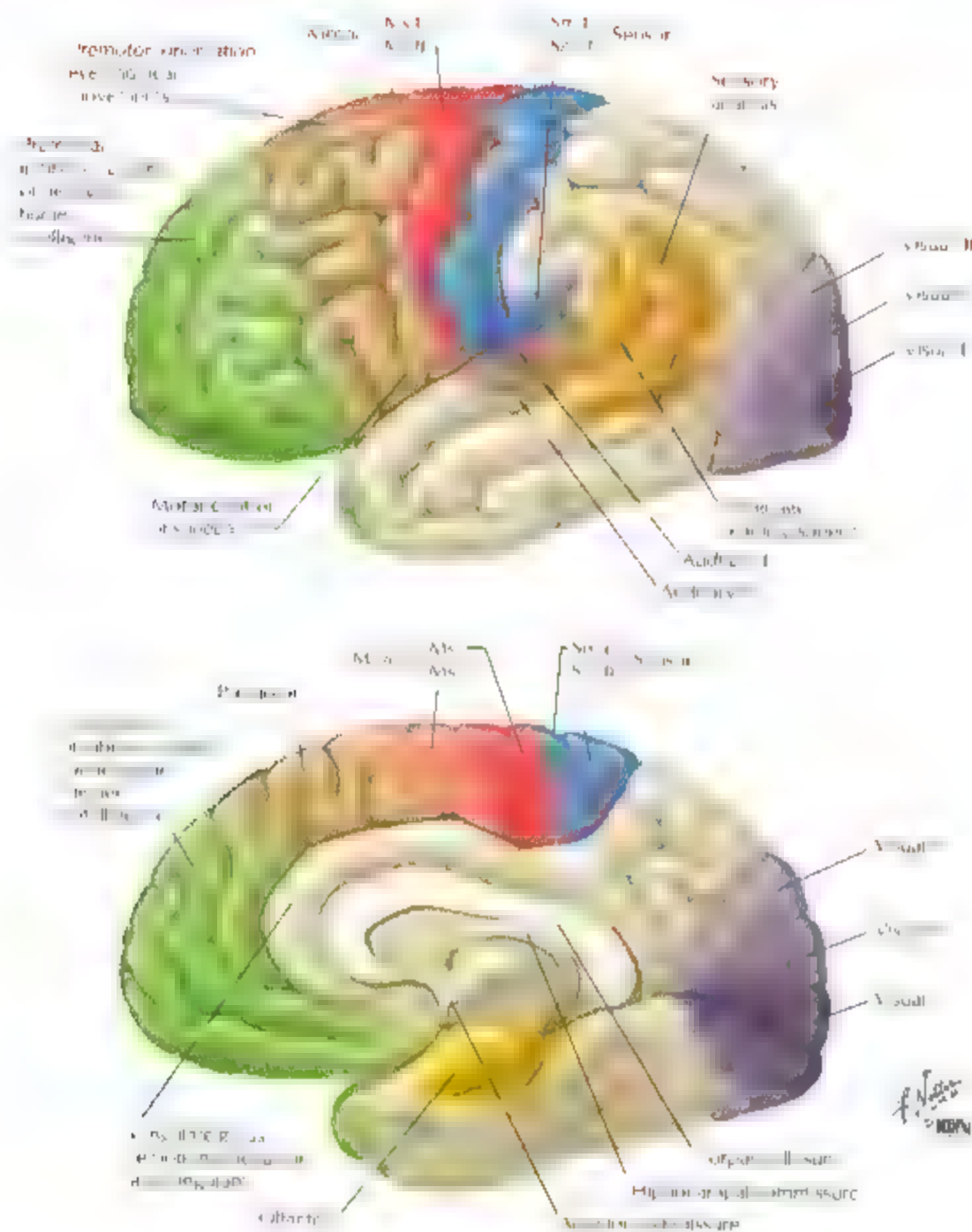


FIGURE 2.19 CEREBRAL CORTEX: LOCALIZATION OF FUNCTION AND ASSOCIATION PATHWAYS

The cerebral cortex is organized into functional regions, a process called functional localization. Some areas are involved in specific functions, such as motor areas, sensory areas, and association areas. The cerebral cortex participates in a variety of functions, including:

aspects of perception, language, and executive functions. Higher cognitive functions, such as perception, sensory integration, and memory, are associated with complex neural activity. The cerebral cortex is associated with a variety of functions, including:

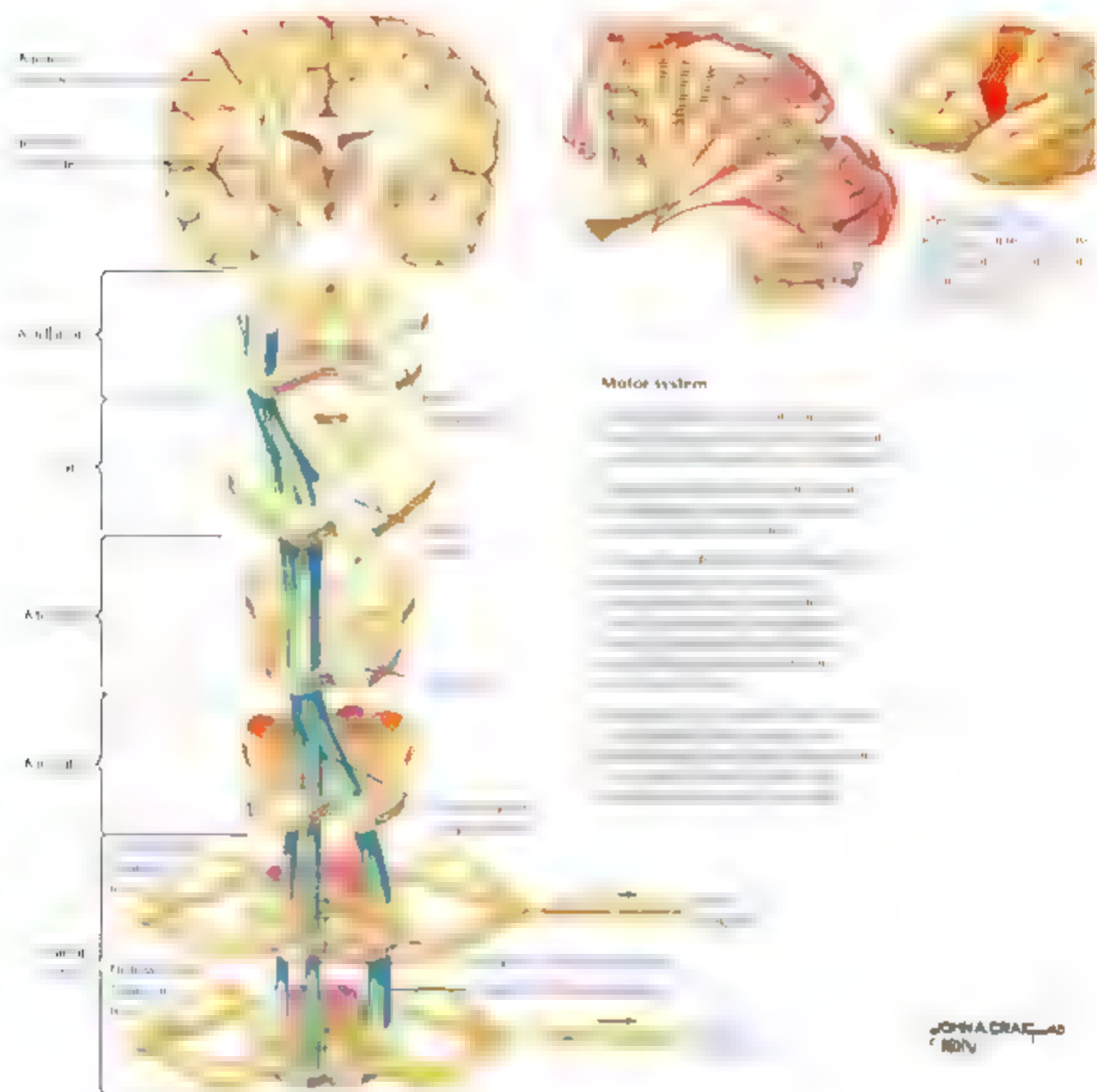


FIGURE 2.20 CORTICOSPINAL TRACTS

The corticospinal tract is the main motor pathway for voluntary movement. It originates in the cerebral cortex and descends through the brainstem and spinal cord to the motor neurons in the ventral horn of the spinal cord. The corticospinal tract is composed of two main parts: the lateral corticospinal tract and the ventral corticospinal tract. The lateral corticospinal tract is the larger of the two and is responsible for the control of fine, skilled movements. The ventral corticospinal tract is smaller and is responsible for the control of gross, unskilled movements.

The corticospinal tract is a descending pathway that carries motor information from the cerebral cortex to the spinal cord. It is composed of two main parts: the lateral corticospinal tract and the ventral corticospinal tract. The lateral corticospinal tract is the larger of the two and is responsible for the control of fine, skilled movements. The ventral corticospinal tract is smaller and is responsible for the control of gross, unskilled movements.

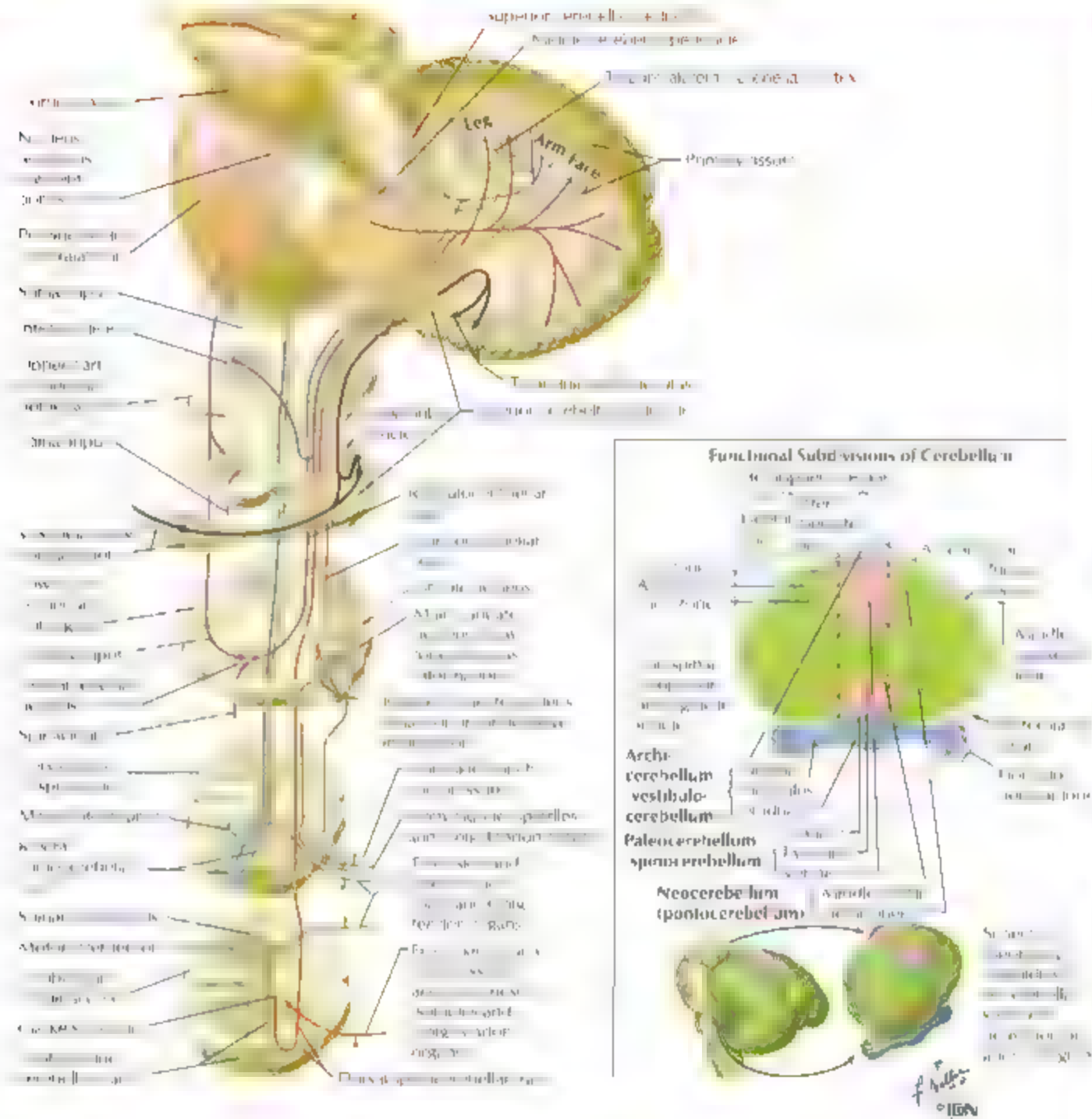


FIGURE 2.21 CEREBELLAR AFFERENT PATHWAYS

The cerebellum is a small, highly folded structure located at the back of the brain, below the occipital lobes. It is responsible for coordinating movement, balance, and posture. The cerebellum is divided into three main functional regions: the archicerebellum (vestibulocerebellum), the paleocerebellum (spinocerebellum), and the neocerebellum (pontocerebellum). The archicerebellum is primarily involved in balance and eye movements. The paleocerebellum is primarily involved in posture and locomotion. The neocerebellum is primarily involved in fine motor control and coordination. The cerebellar cortex is divided into the molecular layer, the Purkinje cell layer, and the granular layer. The cerebellar nuclei are also shown, including the dentate nucleus, emboliform nucleus, globose nucleus, and uvula nucleus. The diagram illustrates the afferent pathways from the brainstem, spinal cord, and sensory organs to the cerebellum.

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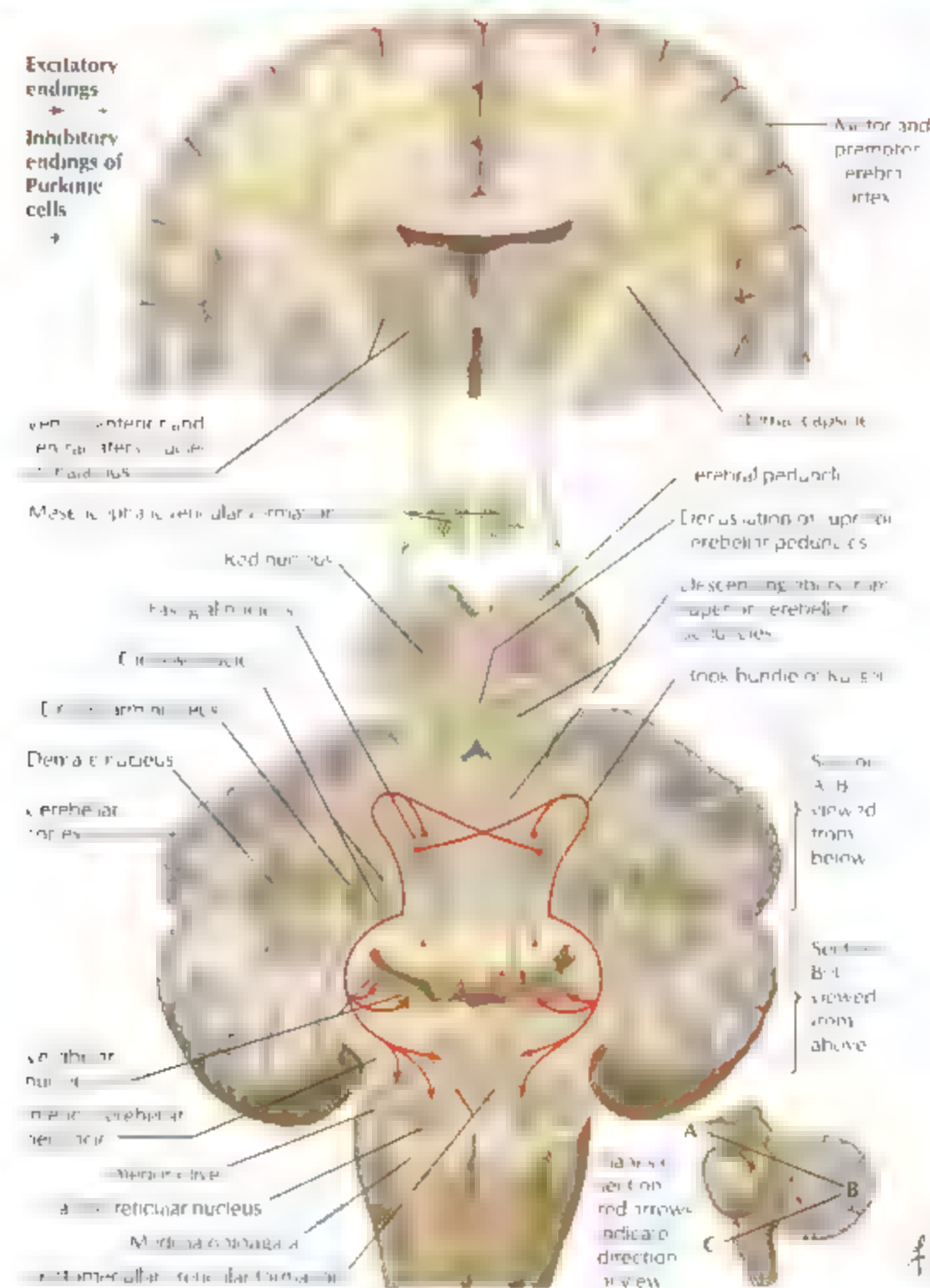


FIGURE 2.22 CEREbellAR EFFERENT PATHWAYS

The cerebellum plays an important role in coordinating voluntary movements. It receives descending motor pathways from the cerebral cortex and brainstem. The cerebellum is primarily involved in controlling posture and balance and movement of the limbs. It also receives sensory input from the eyes, ears, and proprioceptors. The pathways for these inputs are shown in the diagram.

The cerebellum is involved in the planning and coordination of movements. It receives input from the cerebral cortex and brainstem. The cerebellum is primarily involved in controlling posture and balance and movement of the limbs. It also receives sensory input from the eyes, ears, and proprioceptors. The pathways for these inputs are shown in the diagram.

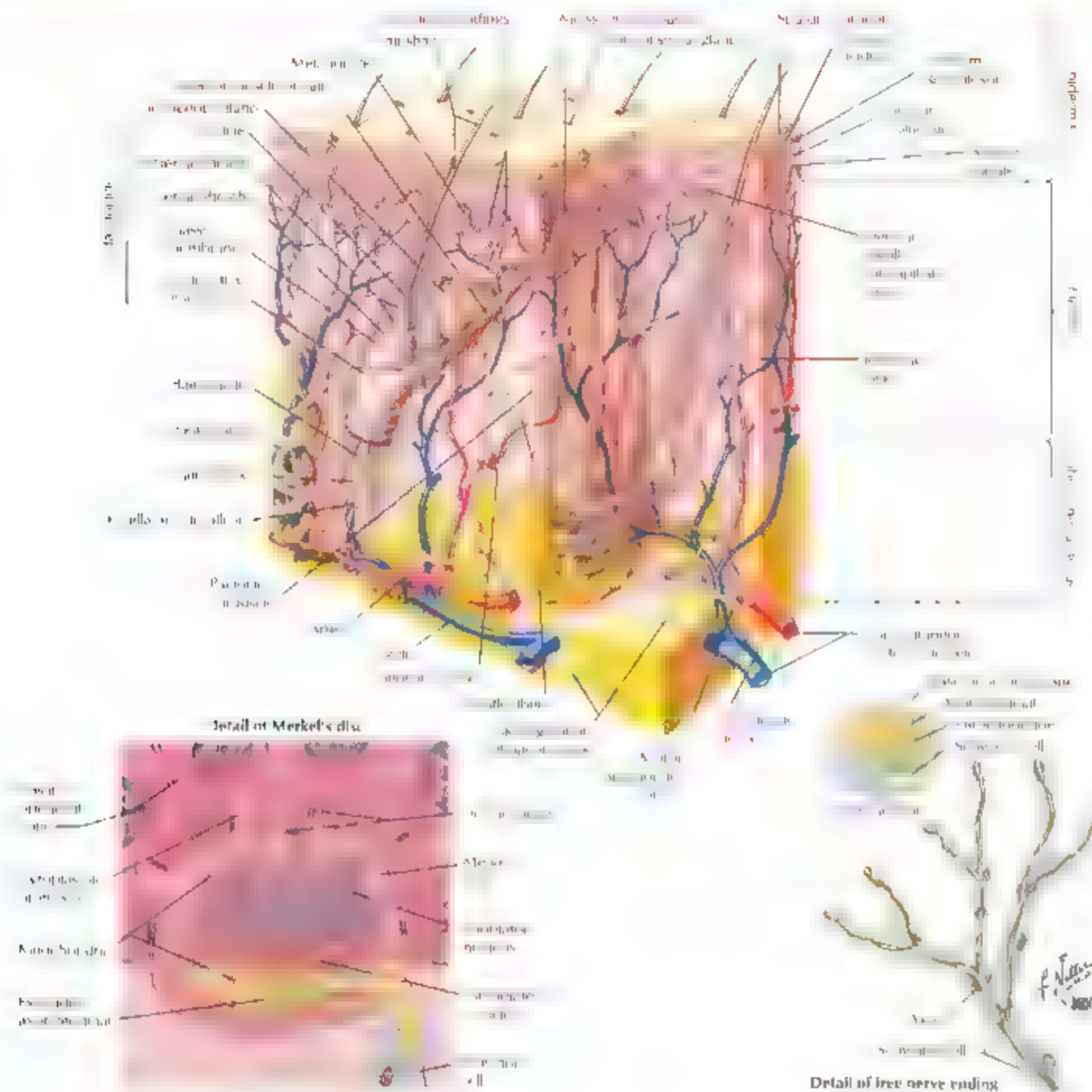


FIGURE 2.23 SKIN AND CUTANEOUS RECEPTORS

Cutaneous receptors are specialized for detecting various types of stimuli. The most common types of receptors are the free nerve endings, which are distributed throughout the skin and are responsible for detecting pain, temperature, and light touch. Other types of receptors include the Merkel's disks, which are specialized for detecting light touch and pressure, and the Meissner's corpuscles, which are specialized for detecting light touch and vibration. The Pacinian corpuscles are specialized for detecting deep pressure and vibration.

The diagram shows the distribution of these receptors in the skin. The free nerve endings are distributed throughout the epidermis and dermis. The Merkel's disks are located in the epidermis, and the Meissner's corpuscles are located in the dermal papillae of the epidermis. The Pacinian corpuscles are located in the deep dermis. The diagram also shows the neural pathways for these receptors, which involve the sensory neurons and the motor neurons.

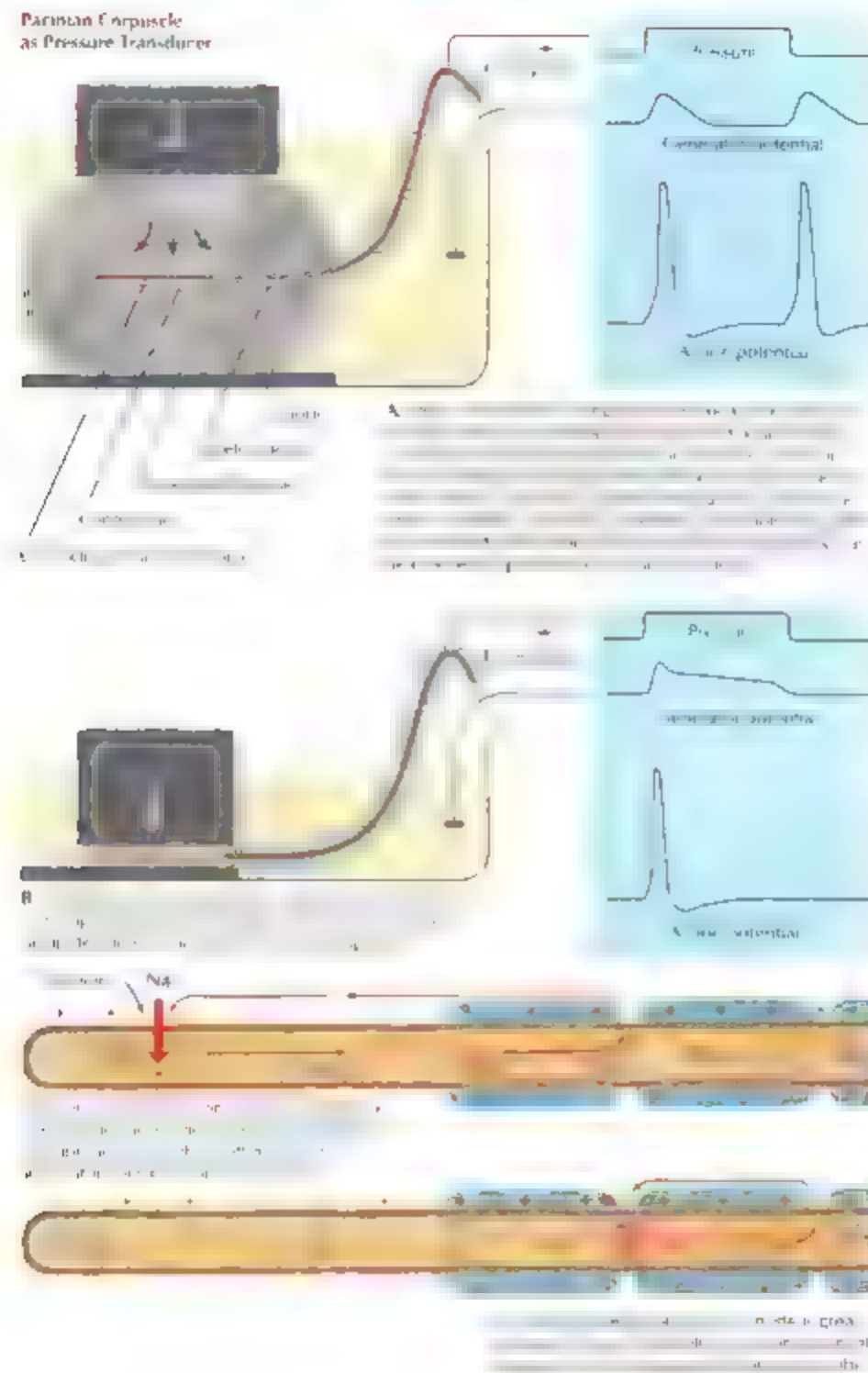


FIGURE 2.24 PACINIAN CORPUSCLE

Pacinian corpuscles are mechanoreceptors that respond to deep pressure and vibration. They are located in the dermis of the skin and are composed of a central core of non-myelinated A fibers surrounded by concentric layers of lamellae. The lamellae are made of a gelatinous substance and are arranged in a way that they can be compressed and then return to their original shape. This compression and return to shape is what generates the generator potential, which then leads to the action potential.

A Pacinian corpuscle is a mechanoreceptor that responds to deep pressure and vibration. It is composed of a central core of non-myelinated A fibers surrounded by concentric layers of lamellae. The lamellae are made of a gelatinous substance and are arranged in a way that they can be compressed and then return to their original shape. This compression and return to shape is what generates the generator potential, which then leads to the action potential.

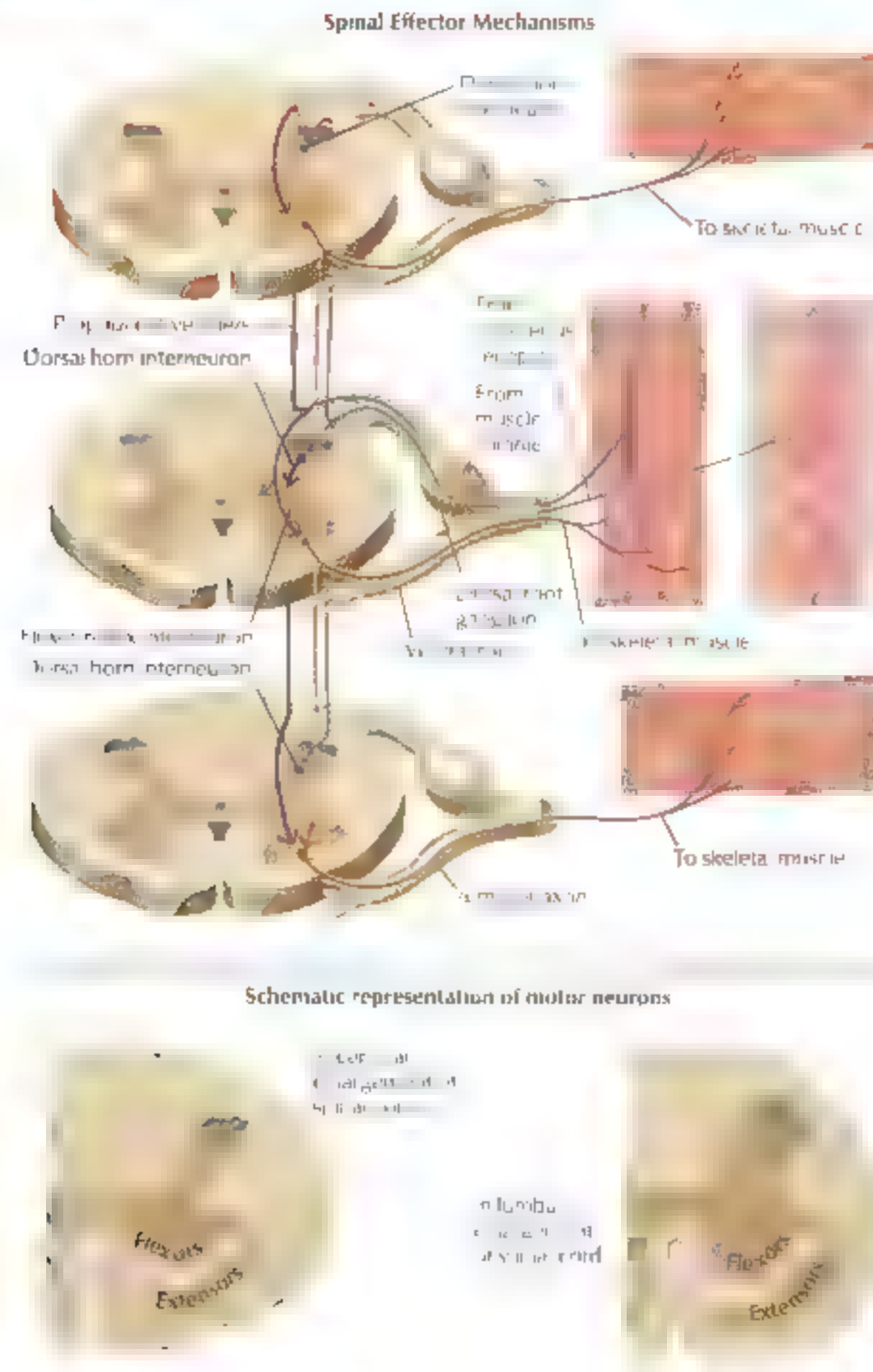


FIGURE 2.25 PROPRIOCEPTION: SPINAL EFFECTOR MECHANISM

Position sense or proprioception involves input from cutaneous mechanoreceptors, ligament organs, and muscle spindles (middle figure of upper panels). Both monosynaptic reflex pathways (middle figure of upper panel) and polysynaptic pathways involving several spinal cord segments (top and bottom figures of upper panels)

initiate muscle contraction reflexes. The lower panels show the somatic distribution of the major motor cell bodies in the ventral horn of the spinal cord that innervate limb muscles (flexor and extensor muscles of upper and lower limbs).

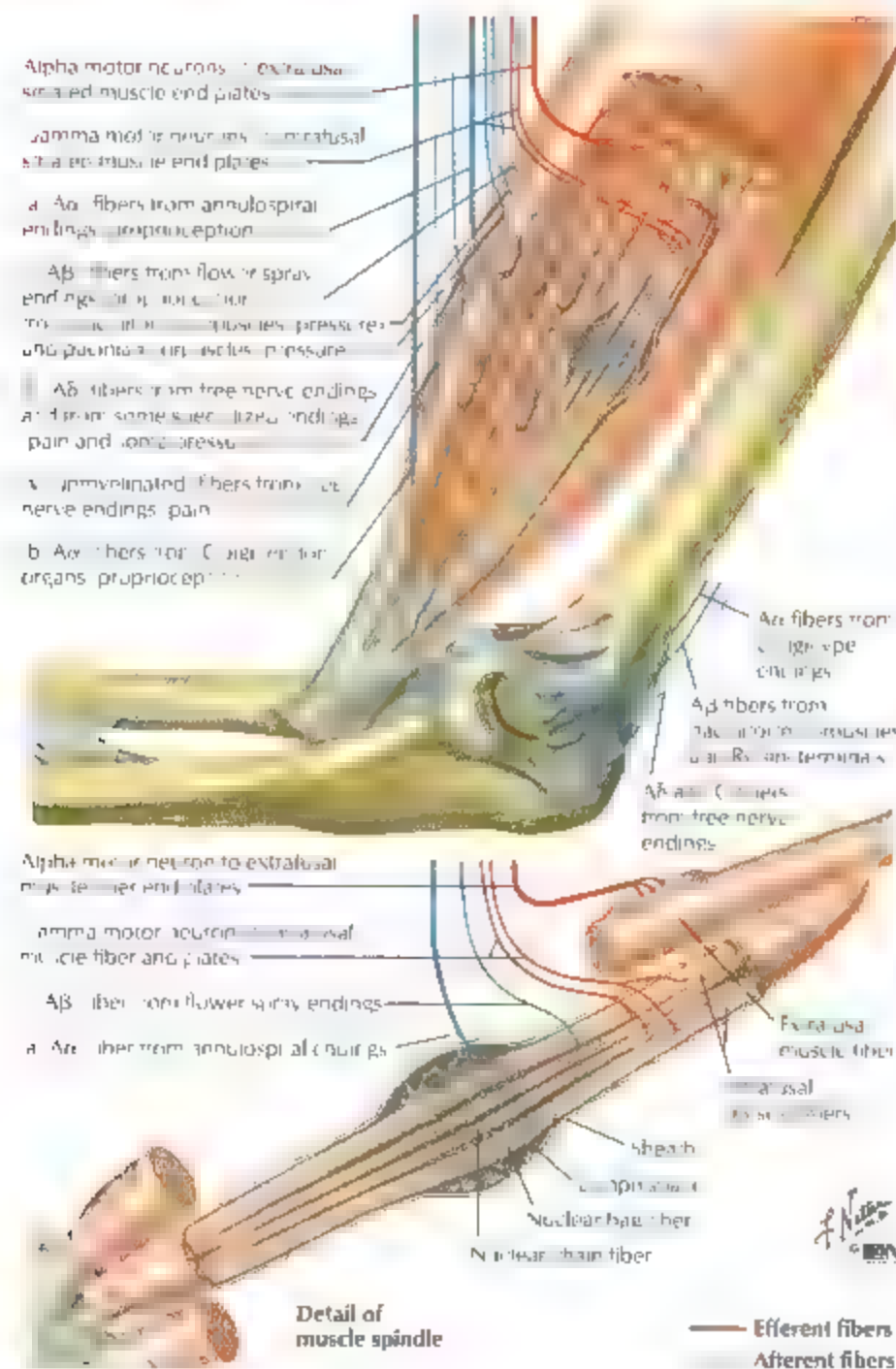


FIGURE 2.26 MUSCLE AND JOINT RECEPTORS

Muscle spindles and Golgi tendon organs send afferent signals to the brain. They convey the position of limbs and help coordinate muscle movement. Muscle spindles convey information on muscle tension and contraction dynamic forces, and muscle Golgi tendon organs. The nuclear bag fibers respond to both dynamic and static forces

whereas the nuclear chain fibers respond to static forces. When an appropriate tension on the nuclear bag and chain fibers, the muscle Golgi tendon organ is activated, overriding the motor unit activity and the Golgi tendon organ causes a reflex relaxation of the muscle.

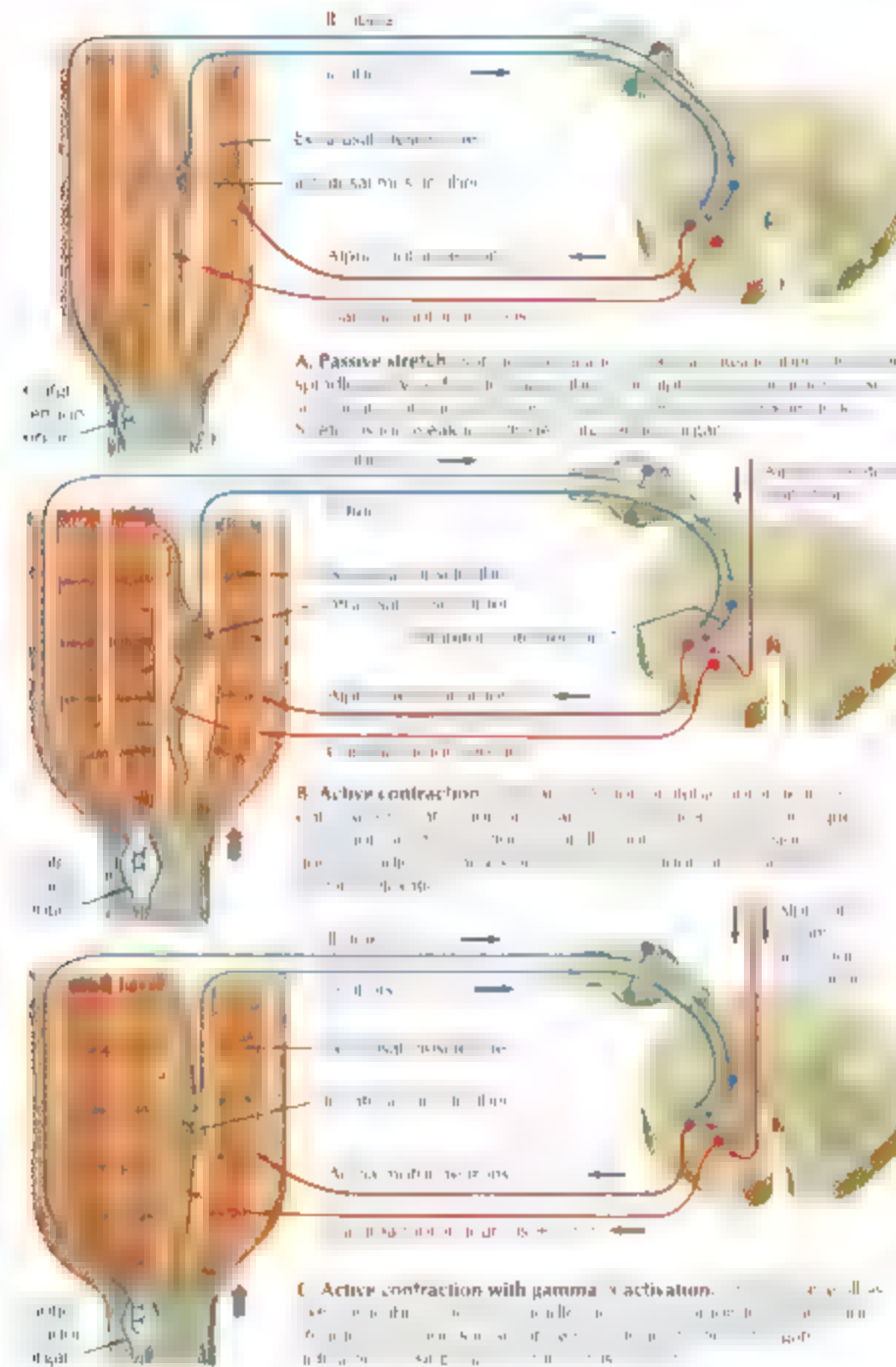


FIGURE 2.27 PROPRIOCEPTIVE REFLEX CONTROL OF MUSCLE TENSION

Diagram illustrating the proprioceptive reflex control of muscle tension. The diagram shows a muscle spindle (Ia and II afferents) and a Golgi tendon organ (Ib afferent) within a muscle. The Ia afferents cross and synapse with alpha motor neurons, while the Ib afferents synapse with gamma motor neurons. In scenario A, passive stretch activates Ia afferents, leading to alpha motor neuron activation and muscle contraction. In scenario B, active contraction activates Ib afferents, leading to gamma motor neuron activation and increased spindle sensitivity. In scenario C, both Ia and Ib afferents are active, leading to both alpha and gamma motor neuron activation and muscle contraction.

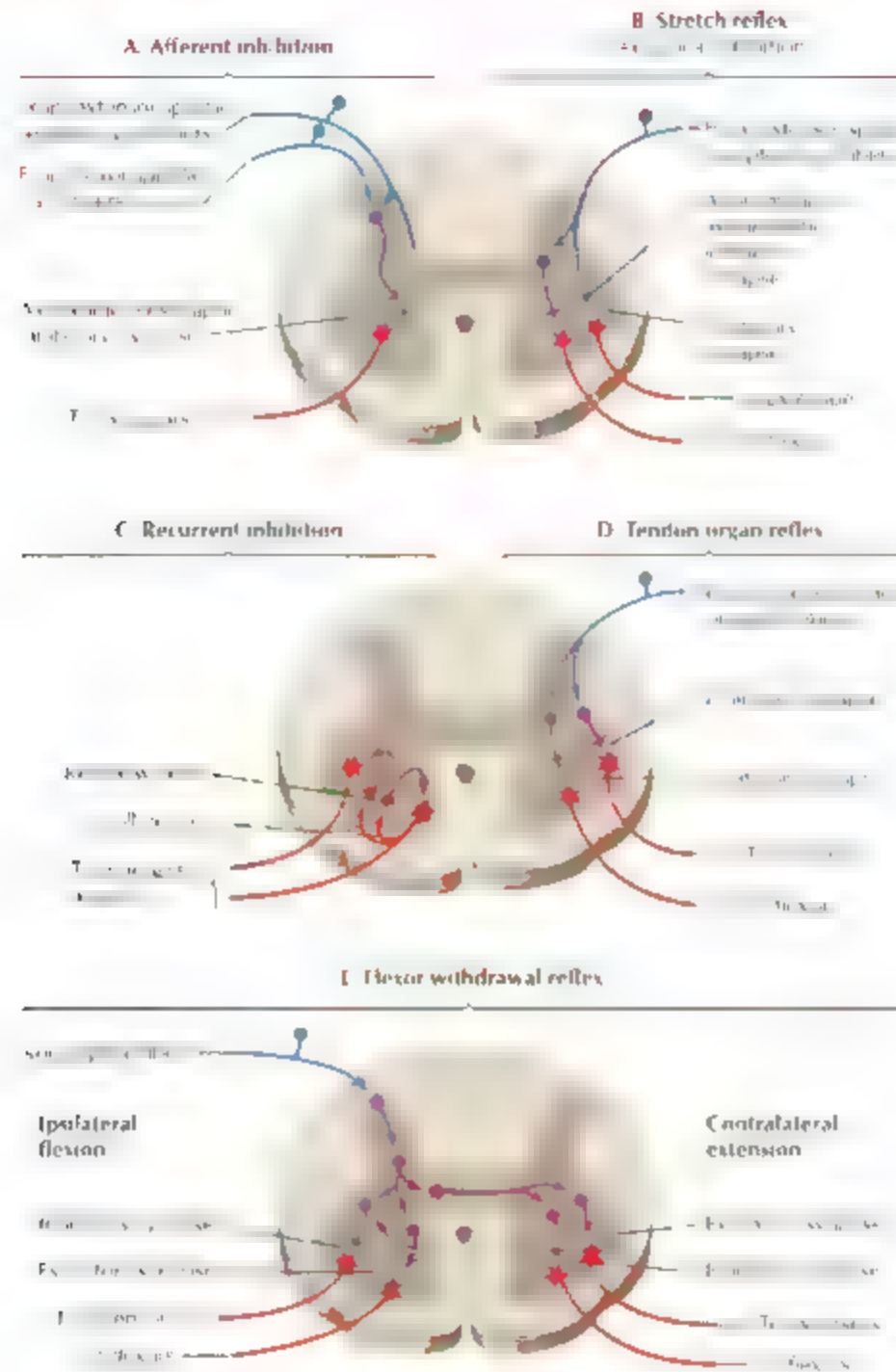


FIGURE 2.28 SPINAL REFLEX PATHWAYS

Summary of the spinal reflex pathways.



in the thalamus, ventral posterior nucleus, whereas the lateral dorsal nucleus relates to the sensory and proprioceptive pathways. Blue and purple lines show the sensory pathways, and the second 4 parallel red lines to the thalamus sensory pathways to the cortex.

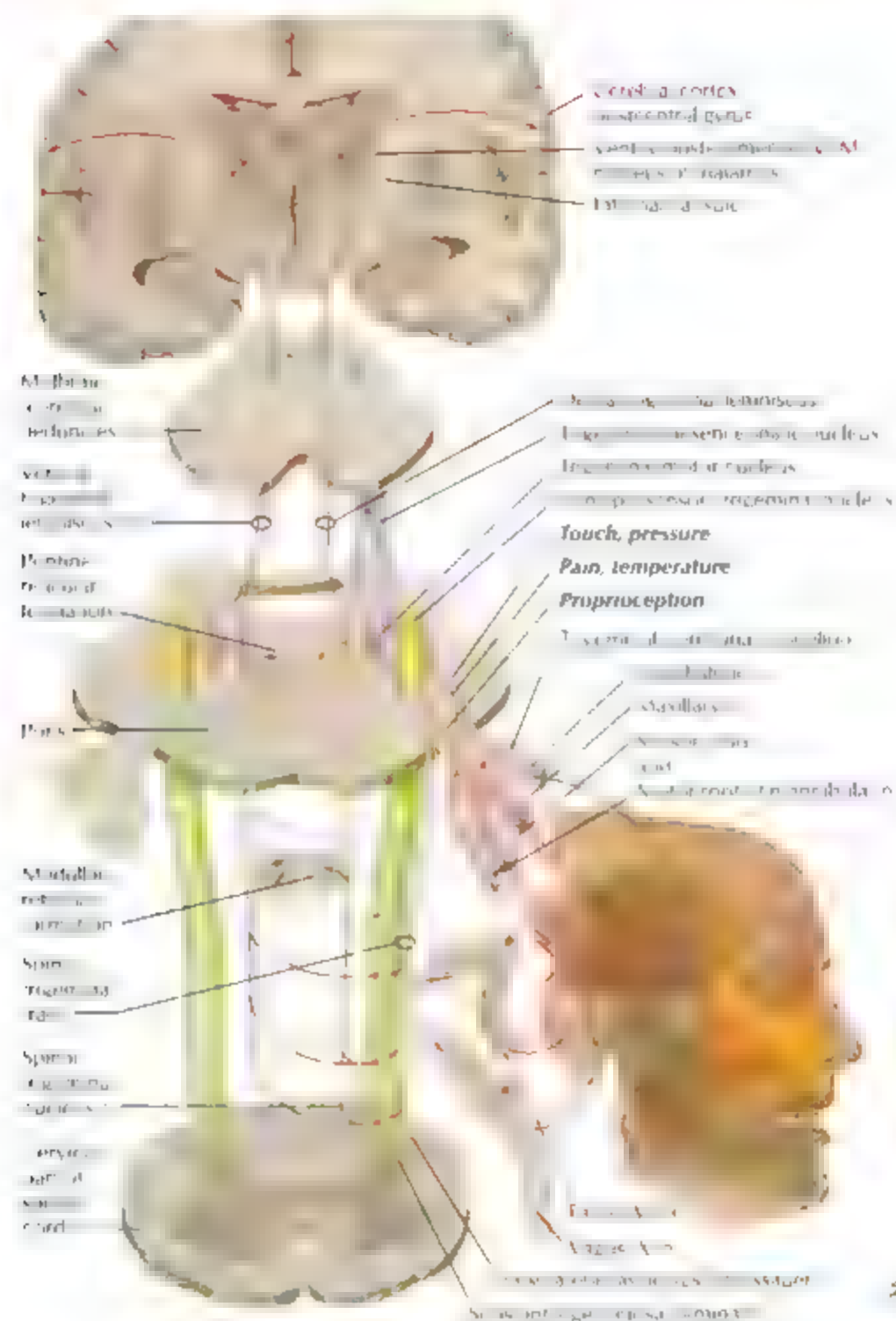


FIGURE 2.30 SOMESTHETIC SYSTEM OF THE HEAD

Nerve cell bodies for touch, pressure, pain, and temperature in the face are in the trigeminal ganglion and nucleus of the trigeminal (CN V) nerve. Cell bodies for proprioception are in the nucleus of the trigeminal (CN V) nerve.

Trigeminal (CN V) nerve cell bodies for touch, pressure, pain, and temperature are in the trigeminal ganglion and nucleus of the trigeminal (CN V) nerve. Cell bodies for proprioception are in the nucleus of the trigeminal (CN V) nerve.

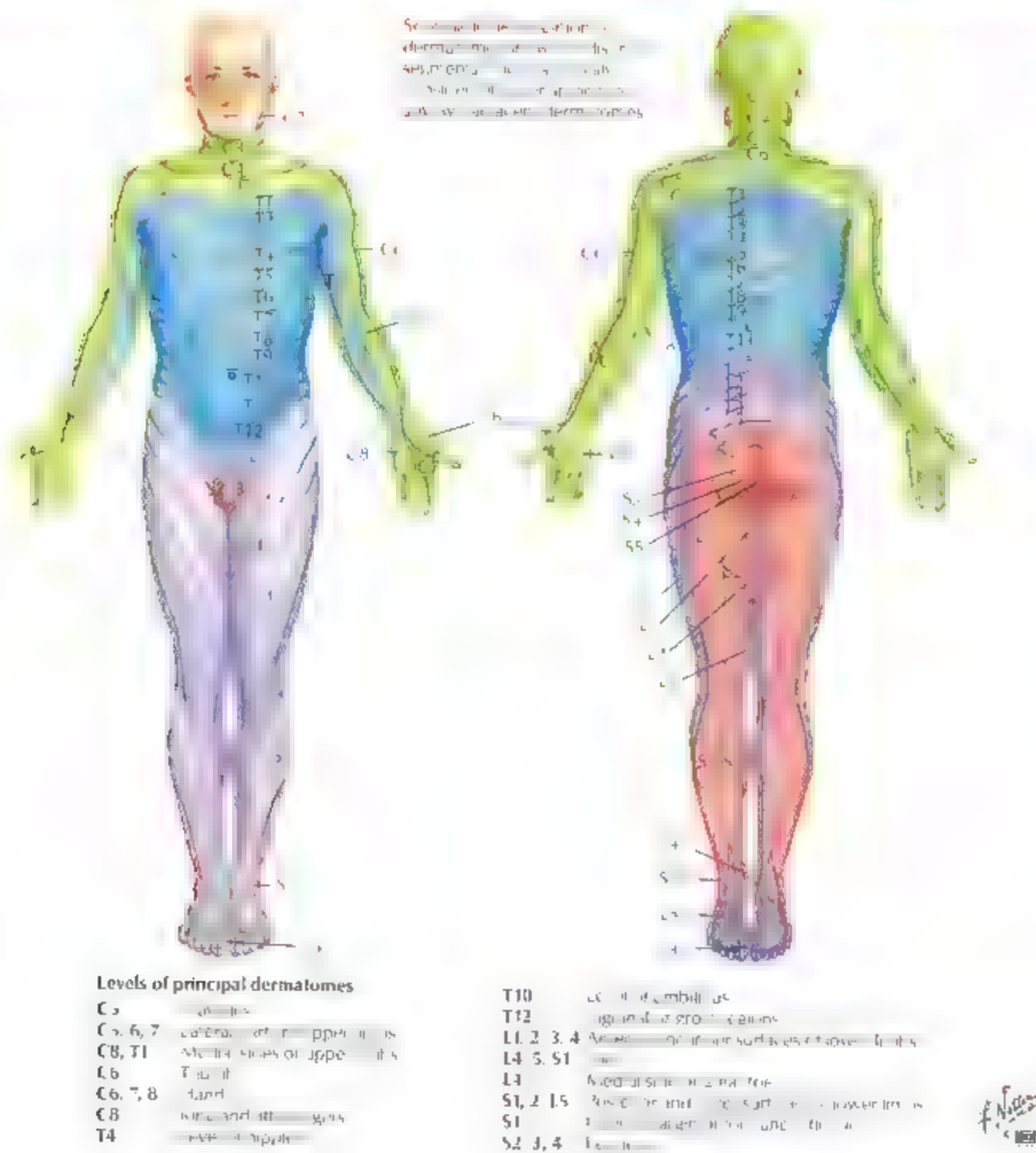


FIGURE 2.31 DERMATOMES

Sensory information from the skin is localized to specific areas of the body, which are the dermatomes. Each dermatome is a specific area of skin that carries sensory information to a specific area of the brain. The dermatomes are organized into segments, and each segment is associated with a specific spinal cord segment.

called a dermatome. This figure shows the dermatome map, which is a key dermatome map used to identify the variability of sensory information from all dermatome segments and to identify the sensory pathways.

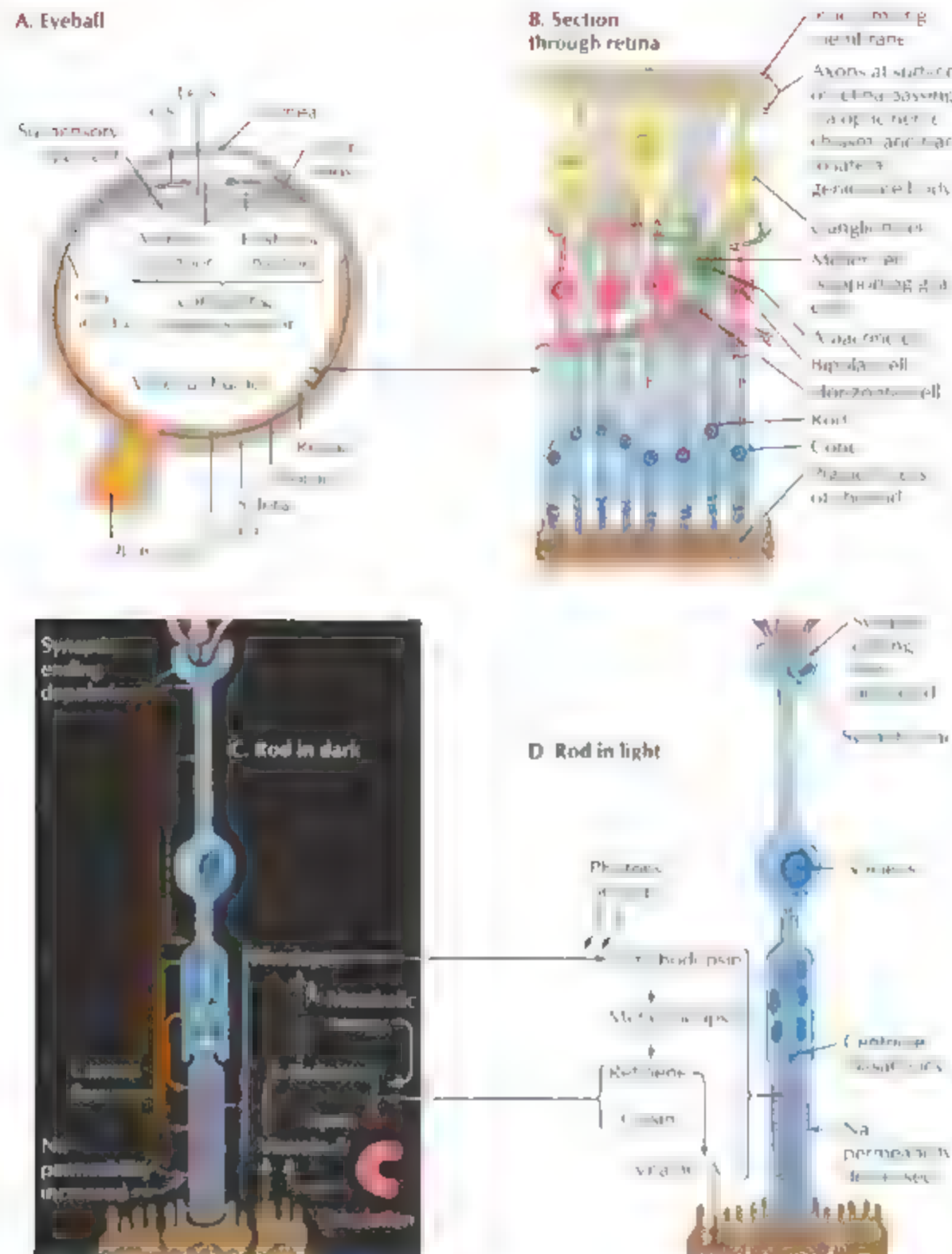


FIGURE 2.32 VISUAL RECEPTORS

The rods and cones of the retina transduce light into electrical signals. As illustrated in the diagram, light enters the eye through the cornea and is focused by the lens onto the retina. The light then passes through the vitreous body and the inner plexiform layer (CML) to reach the photoreceptors. The rods and cones are located in the outer plexiform layer. The rods are responsible for vision in low light conditions, while the cones are responsible for vision in bright light and color vision.

The rod photoreceptor is hyperpolarized in the dark. In the light, the rod responds by hyperpolarizing and other photoreceptors respond by depolarizing. The response to a stimulus results in a depolarization of the receptor membrane.



while information is not an independent variable in the model, it is
 not a constant. It varies with the level of education. The
 model is estimated by ordinary least squares and the results are
 presented in the table below. The results show that the
 coefficient on the variable representing the level of education is
 positive and significant at the 1 percent level.



These afferent pathways and the neural signals they convey are initiated by the hair cells, which depolarize in response to vibration of the basilar membrane. The afferent neural impulses in response to

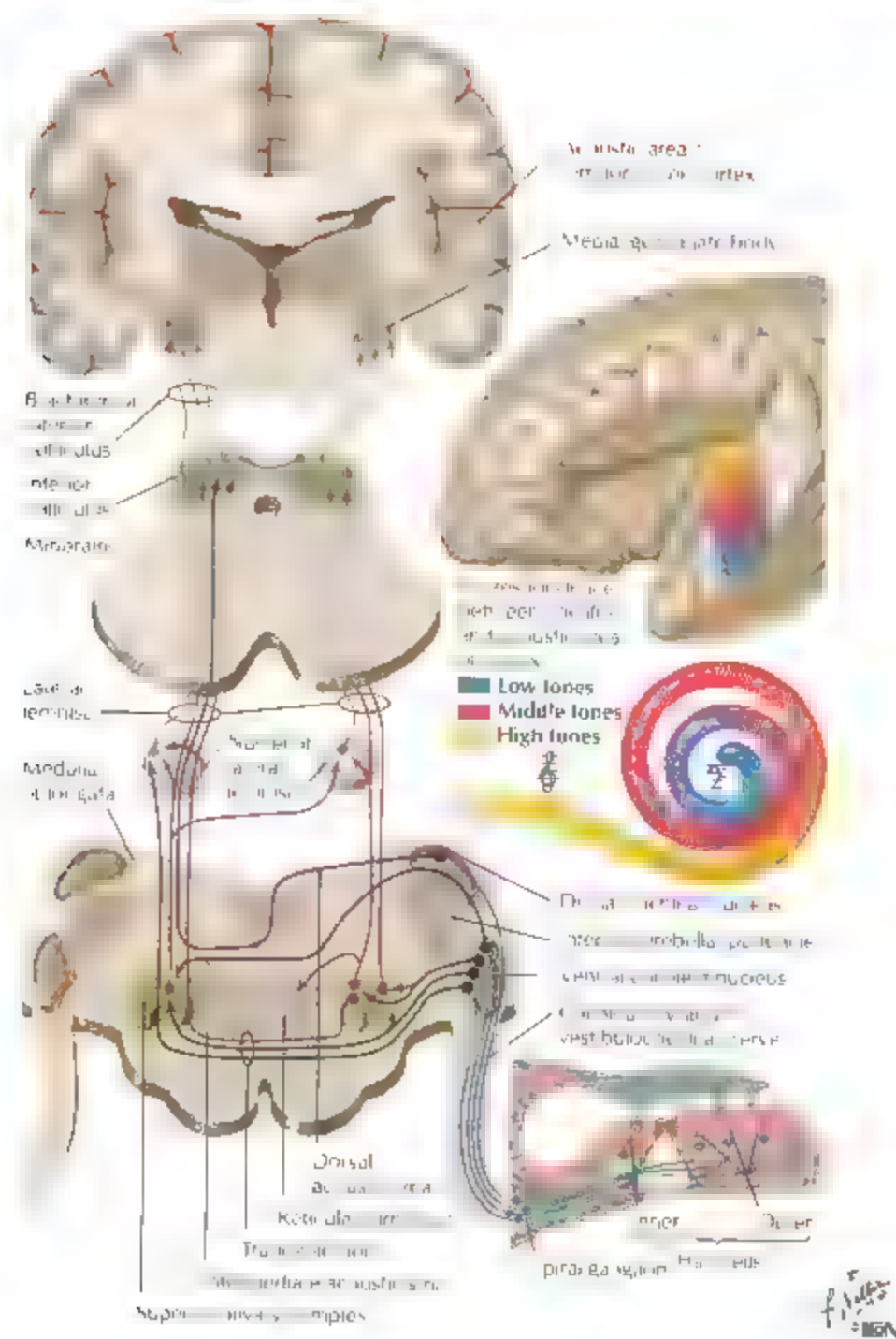


FIGURE 2.35 AUDITORY PATHWAYS

The cochlea transduces sound into electrical signals. Axons convey these signals to the auditory nerve, which carries them to the brain. The auditory pathways are organized hierarchically. From the cochlea, signals are processed through the vestibulocochlear nerve, the superior olivary complex, the medial geniculate body, and finally the auditory cortex.

The auditory cortex is located in the temporal lobe of the brain. It is responsible for processing auditory information and is involved in the perception of sound. The auditory cortex is organized into areas that process different frequencies of sound, from low to high tones.

[illegible]

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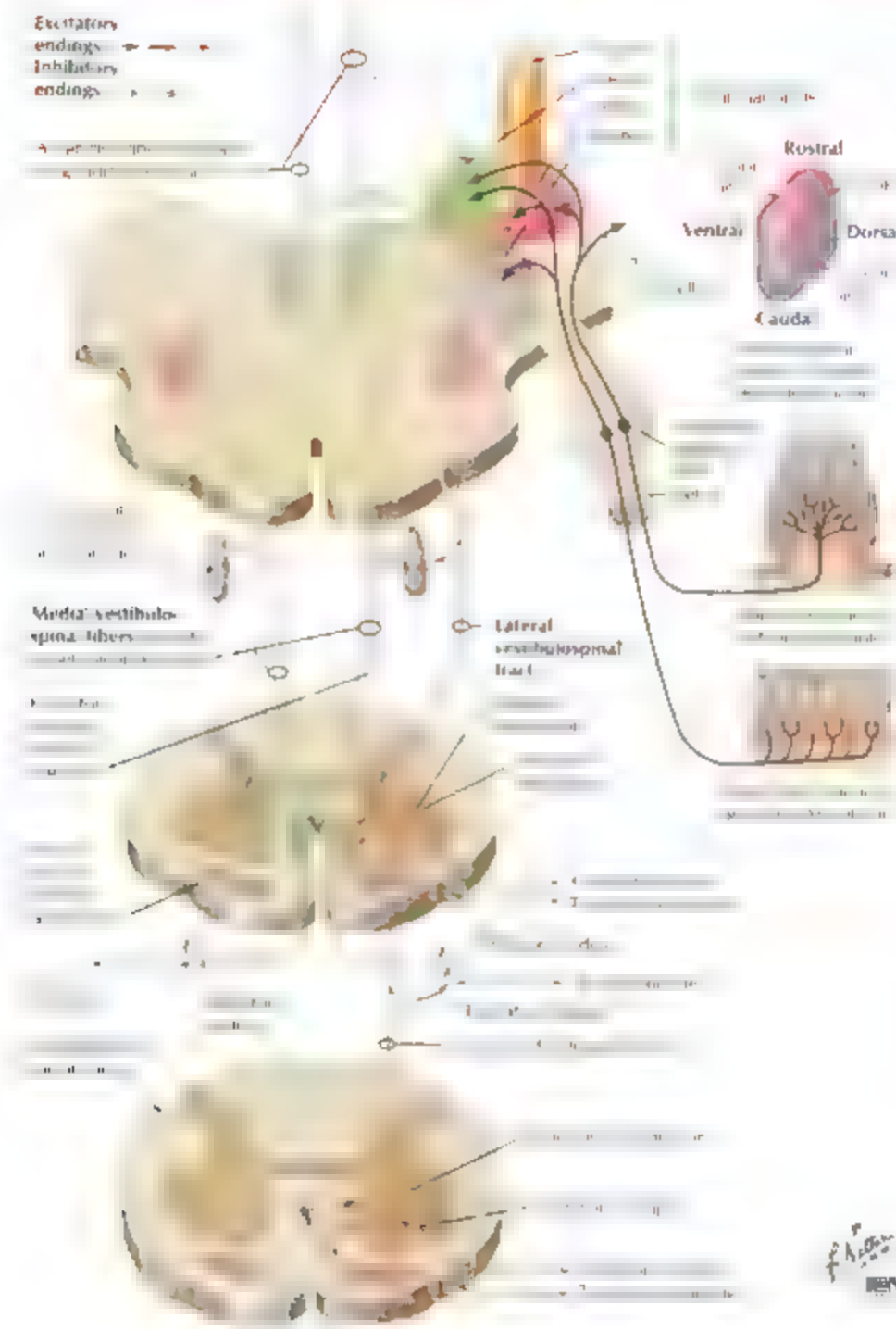


FIGURE 2.37 VESTIBULOSPINAL TRACTS

Vestibulospinal tracts are descending pathways that originate in the vestibular nuclei of the brainstem and descend to the spinal cord. They are responsible for controlling posture and balance. The lateral vestibulospinal tract is the primary pathway for controlling posture and balance, while the medial vestibulospinal tract is primarily involved in controlling head position and eye movements.

The vestibulospinal tracts are part of the descending motor pathways that control posture and balance. They are responsible for controlling the tone of the muscles of the neck, trunk, and limbs. The lateral vestibulospinal tract is the primary pathway for controlling posture and balance, while the medial vestibulospinal tract is primarily involved in controlling head position and eye movements.

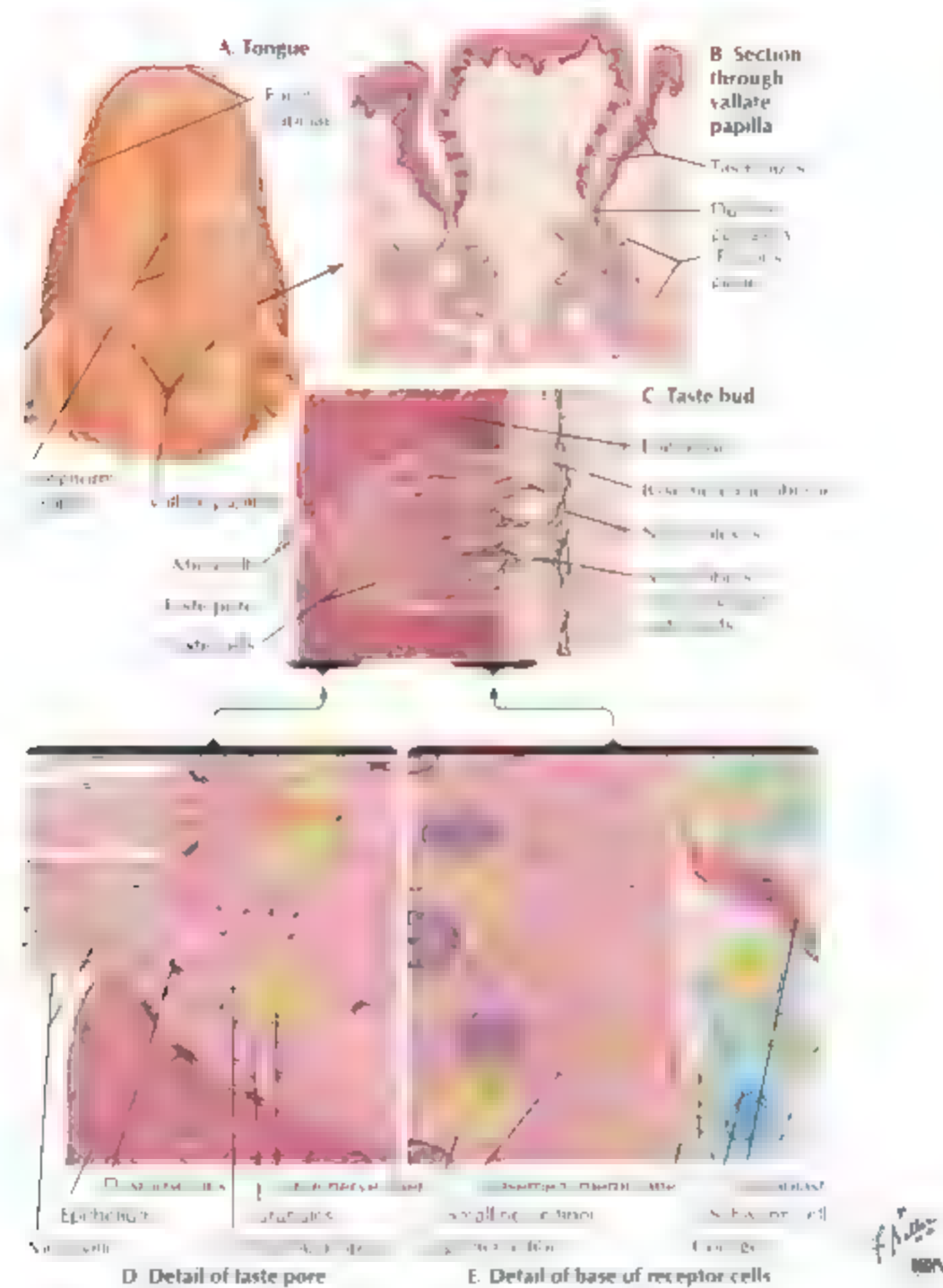


FIGURE 2.38 TASTE RECEPTORS

Taste buds are located on the tongue, specifically on the vallate papillae. Taste buds are composed of several types of cells, including gustatory epithelial cells, which are the primary taste receptors. These cells are arranged in a cluster, with their taste hairs extending into the taste pore. The taste hairs are connected to the base of the receptor cells, which are in turn connected to the gustatory nerve.

neurons connected to the taste buds. A single taste bud can respond to several different tastes. The taste hairs are arranged in a way that allows them to detect sweet, salty, sour, and bitter tastes.

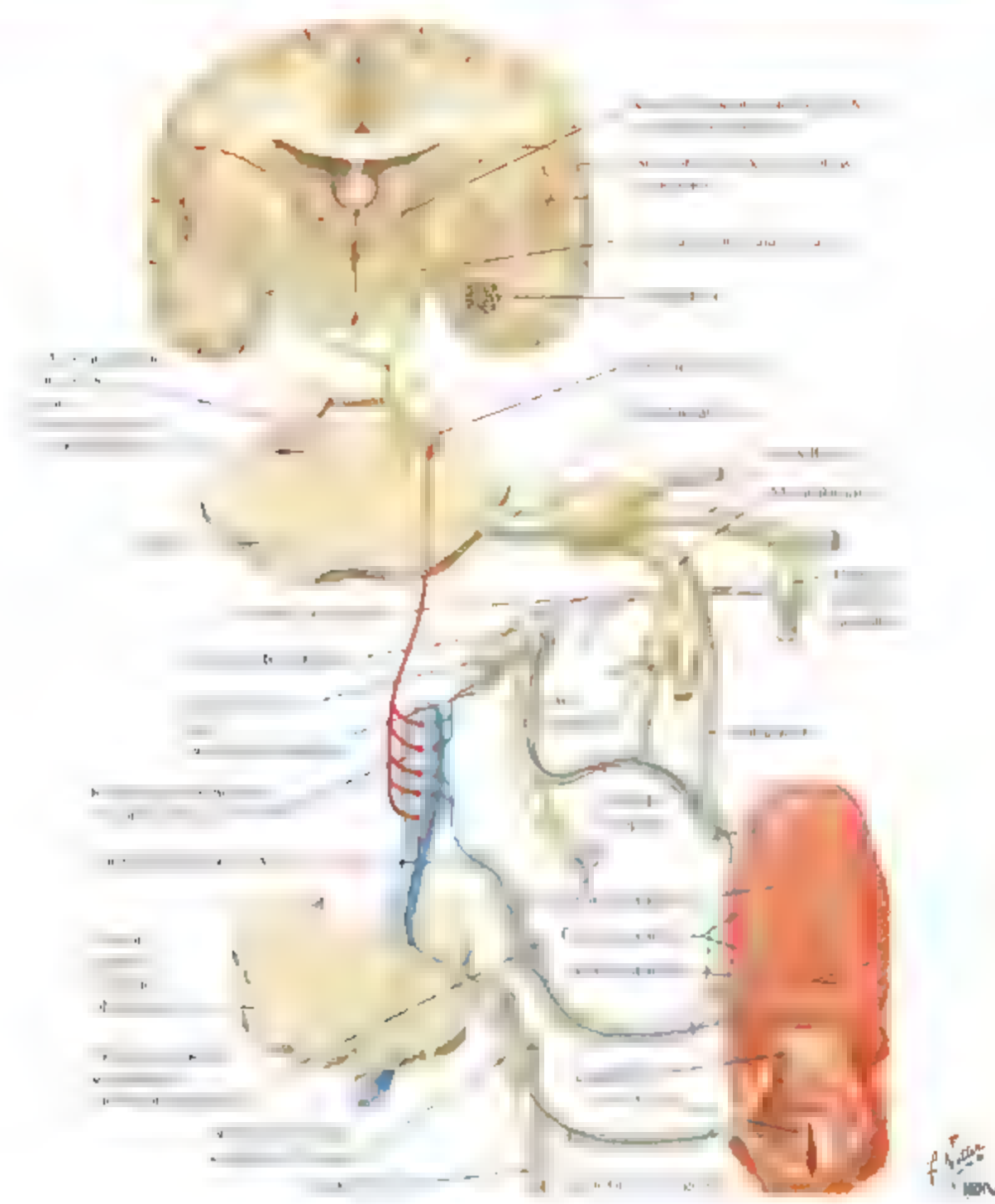


FIGURE 2.39 TASTE PATHWAYS

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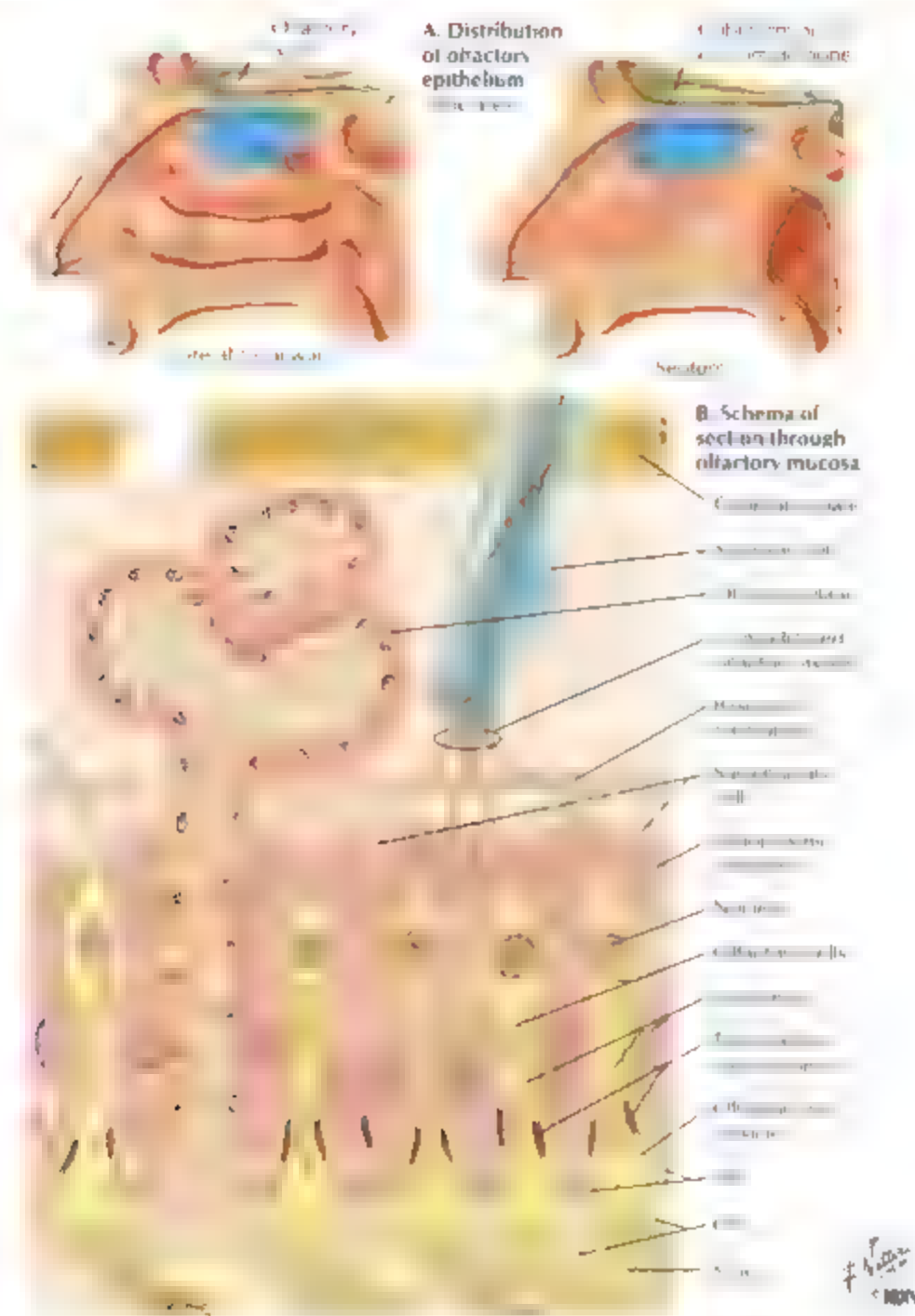


FIGURE 2.40 OLFACTORY RECEPTORS

The olfactory epithelium is located in the upper part of the nasal cavity. It is a specialized epithelium that contains olfactory receptor neurons. These neurons have long dendrites that extend into the mucus layer of the nasal cavity. The axons of these neurons pass through the bone and enter the olfactory bulb.

The olfactory bulb is a small, pear-shaped structure located at the base of the brain. It is the first part of the olfactory system. The olfactory bulb contains glomeruli, which are clusters of olfactory receptor neuron axons. The glomeruli are surrounded by a layer of plexiform fibers.

[illegible]

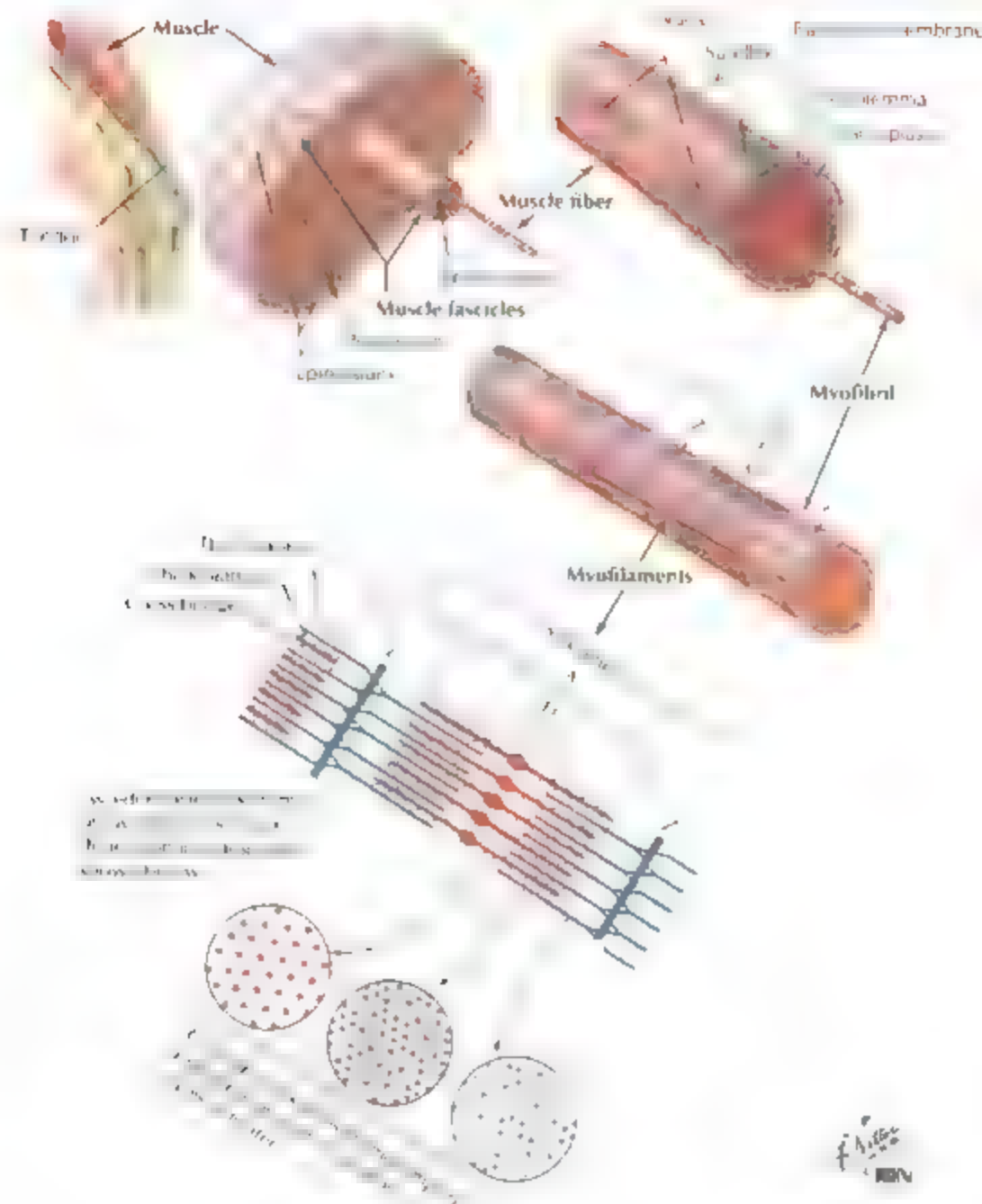


FIGURE 3.1 ORGANIZATION OF SKELETAL MUSCLE

Skeletal muscle is specialized for contraction. The muscle fiber is the basic unit of contraction. The muscle fiber is a long, cylindrical cell. The muscle fiber is surrounded by a cell membrane. The muscle fiber is surrounded by a cell membrane. The muscle fiber is surrounded by a cell membrane.

The muscle fiber is surrounded by a cell membrane. The muscle fiber is surrounded by a cell membrane. The muscle fiber is surrounded by a cell membrane. The muscle fiber is surrounded by a cell membrane.

Segment of muscle fiber greatly enlarged to show sarcoplasmic structures and inclusions

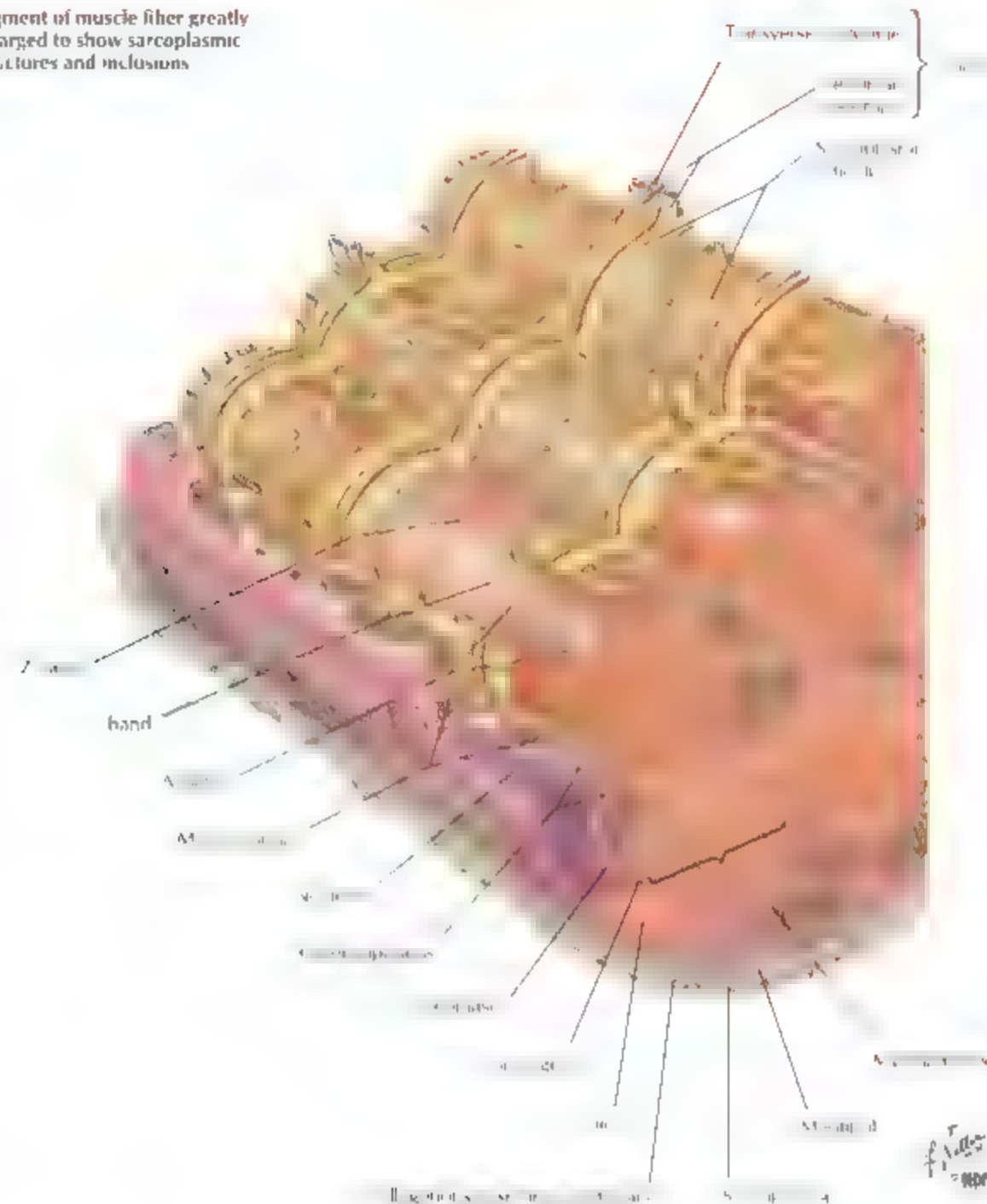


FIGURE 3.2 SARCOPLASMIC RETICULUM

The sarcoplasmic reticulum forms an elaborate network within the cell that stores and releases intracellular Ca^{2+} . The sarcoplasmic reticulum is composed of two main parts: the sarcoplasmic reticulum (SR) and the terminal cisternae. The SR is a network of tubular structures that store and release calcium ions. The terminal cisternae are large, dilated ends of the SR that store calcium ions. The terminal cisternae are connected to the SR by narrow channels called desmosomes.

with two terminal cisternae of the sarcoplasmic reticulum. The terminal cisternae are large, dilated ends of the SR that store calcium ions. Depolarization of the muscle sarcolemma travels down the T-tubules and causes the release of calcium from the sarcoplasmic reticulum (Figure 3.2).

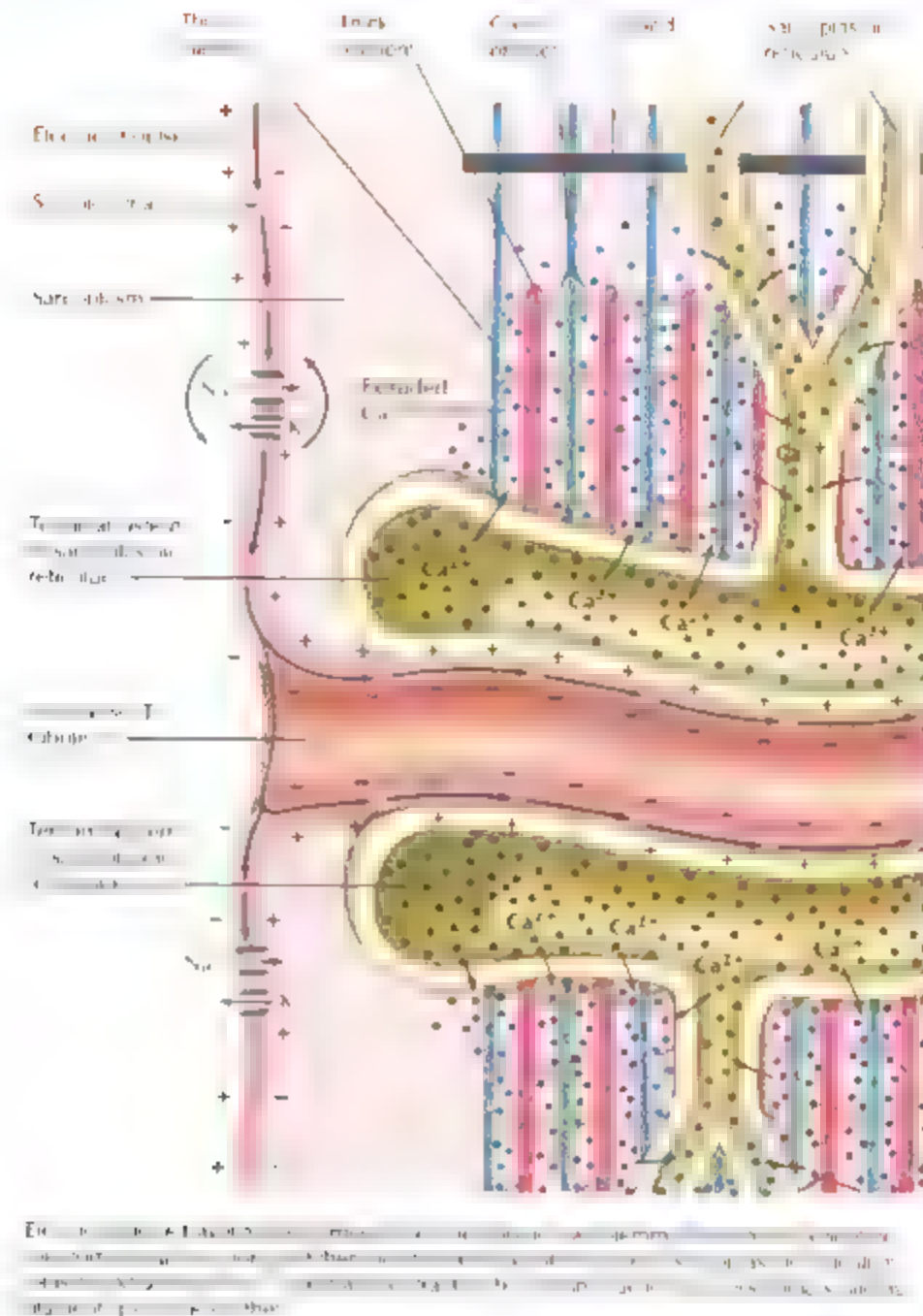
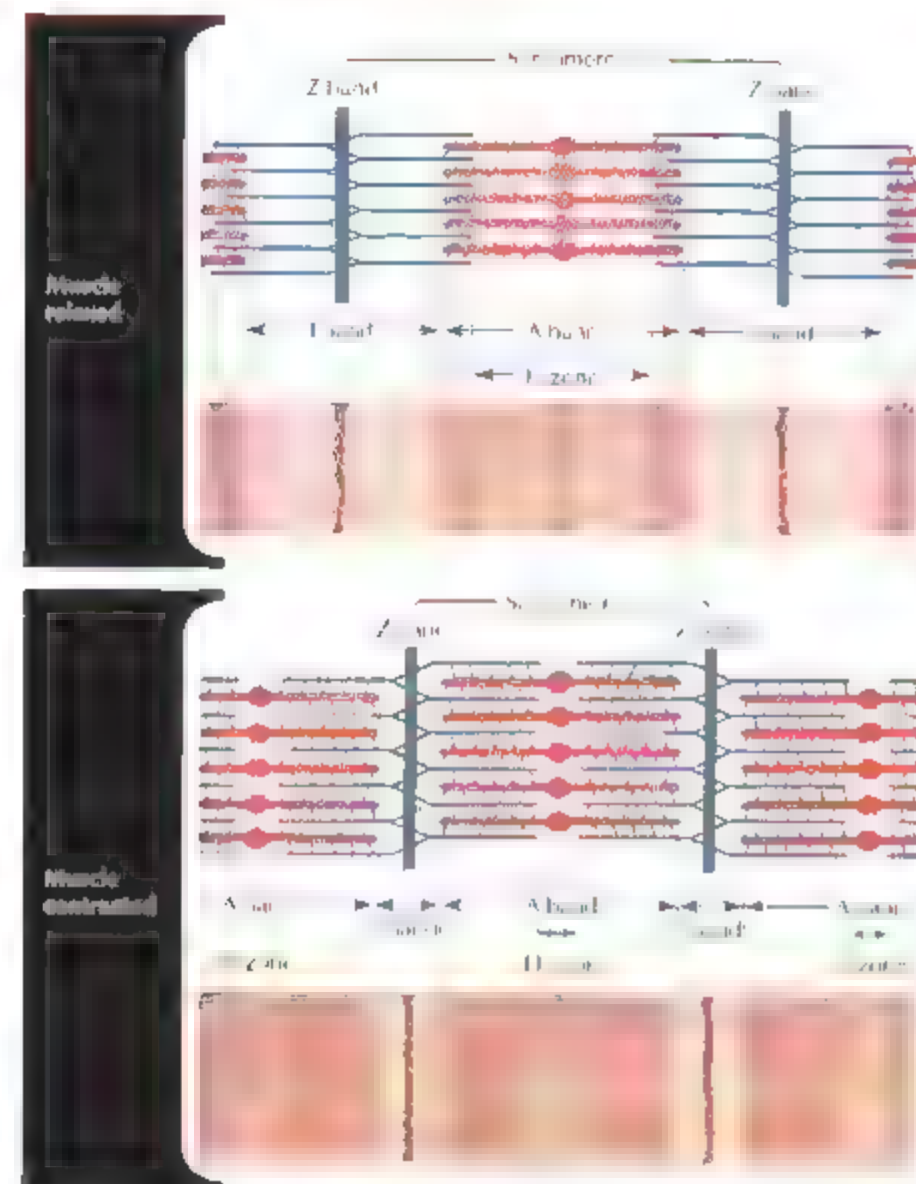


FIGURE 3.3 EXCITATION-CONTRACTION COUPLING

When an action potential arrives at the sarcolemma, it causes the opening of voltage-gated Na^+ channels. This leads to a rapid depolarization of the sarcolemma, which is followed by the opening of voltage-gated Ca^{2+} channels. The resulting Ca^{2+} influx into the cell causes the opening of ryanodine receptors on the sarcoplasmic reticulum, which leads to the release of Ca^{2+} from the SR into the sarcoplasm. The released Ca^{2+} then binds to troponin, which initiates the contraction of the myofibrils.

Let us call this process "excitation-contraction coupling." The whole process is initiated by an action potential arriving at the sarcolemma. The resulting Ca^{2+} influx into the cell causes the opening of ryanodine receptors on the sarcoplasmic reticulum, which leads to the release of Ca^{2+} from the SR into the sarcoplasm. The released Ca^{2+} then binds to troponin, which initiates the contraction of the myofibrils.



During relaxation, the actin and myosin filaments return to their resting lengths. The H-zone reappears, and the sarcomere returns to its original state. The diagram shows the sarcomere returning to its original state after contraction.

FIGURE 3-4 MUSCLE CONTRACTION AND RELAXATION

The sliding—the actin and myosin filaments move and overlap—contraction. This sliding movement is the result of the myosin binding to the actin, forming a cross-bridge.

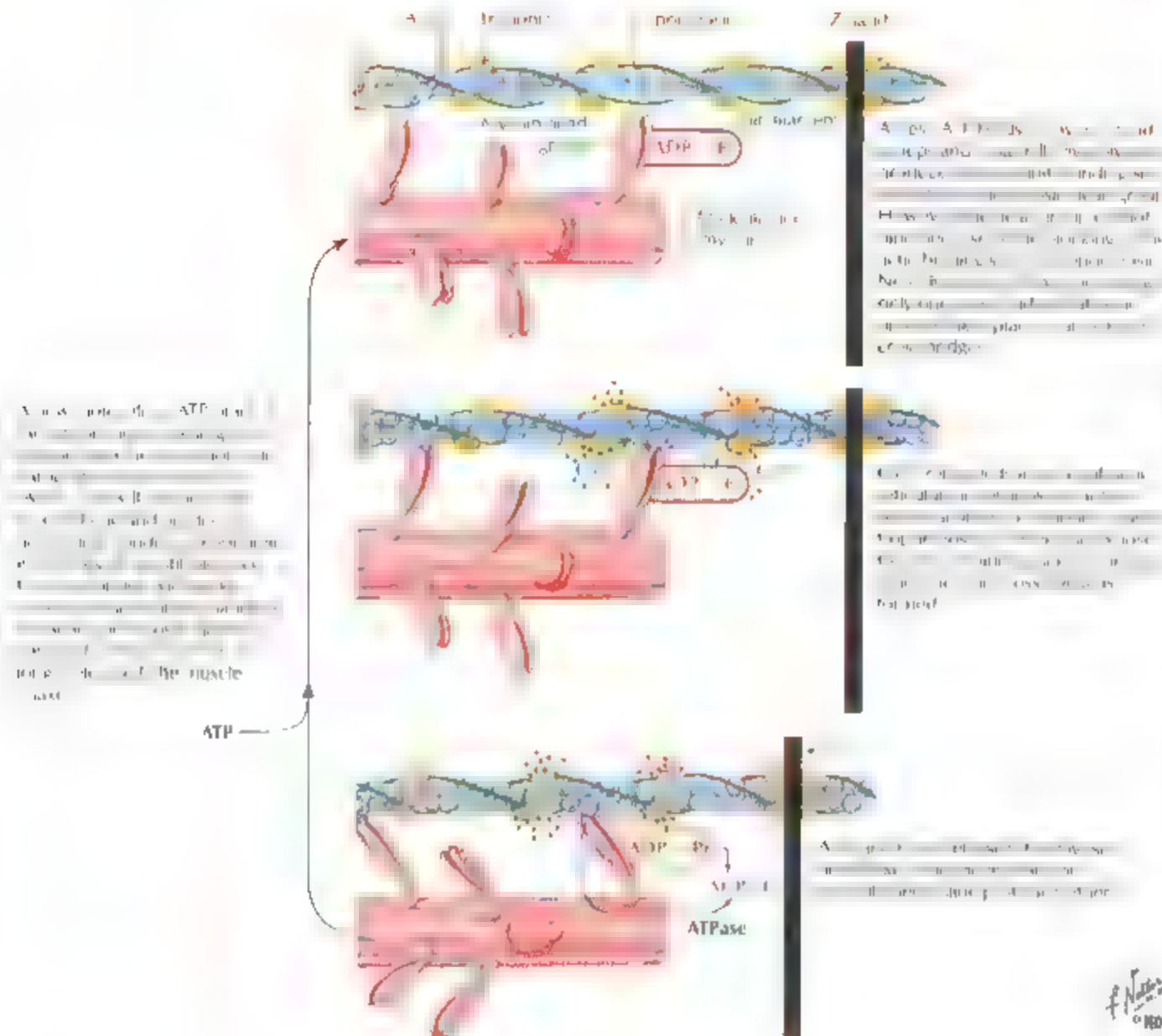


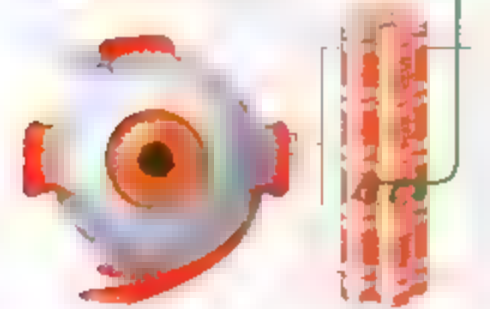
FIGURE 3.5 BIOCHEMICAL MECHANICS OF MUSCLE CONTRACTION

The myosin head is a globular protein that is attached to the actin filament. The myosin head is in a "cocked" position, ready to pull. The myosin head is now in a "relaxed" position, and ATP is released. The myosin head is detached from the actin filament. ATP is hydrolyzed to ADP and inorganic phosphate (Pi), which are then released. The myosin head is now in a "cocked" position, ready to pull again.

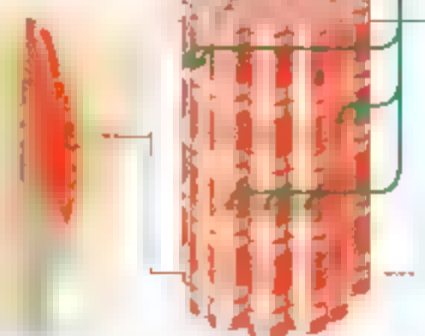
When the myosin head is attached to the actin filament, it is in a "cocked" position, ready to pull. The myosin head is now in a "relaxed" position, and ATP is released. The myosin head is detached from the actin filament. ATP is hydrolyzed to ADP and inorganic phosphate (Pi), which are then released. The myosin head is now in a "cocked" position, ready to pull again.

Variation in Size of Motor Unit

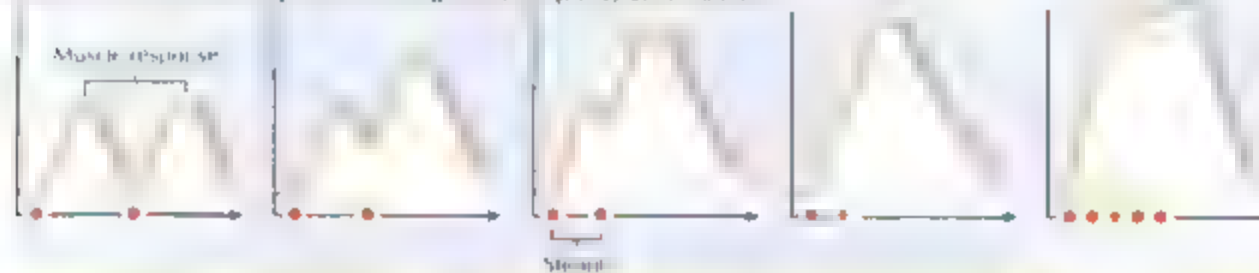
Small motor units

Examples: fine perturbation movements
e.g. quivering eyes

Large motor unit

Examples: gross movements
e.g. muscles of posture

Summation of Muscle Response with Progressive Frequency of Stimulation



Muscle Length-Muscle Tension Relationship

Muscle length is directly related to the degree of overlap between Z-lines. Tension is developed as a result of the degree of overlap between Z-lines. The degree of overlap is directly related to the degree of tension.

As the degree of overlap increases, the tension increases. The degree of overlap is directly related to the degree of tension.

As the degree of overlap increases, the tension increases. The degree of overlap is directly related to the degree of tension.

As the degree of overlap increases, the tension increases. The degree of overlap is directly related to the degree of tension.

As the degree of overlap increases, the tension increases. The degree of overlap is directly related to the degree of tension.

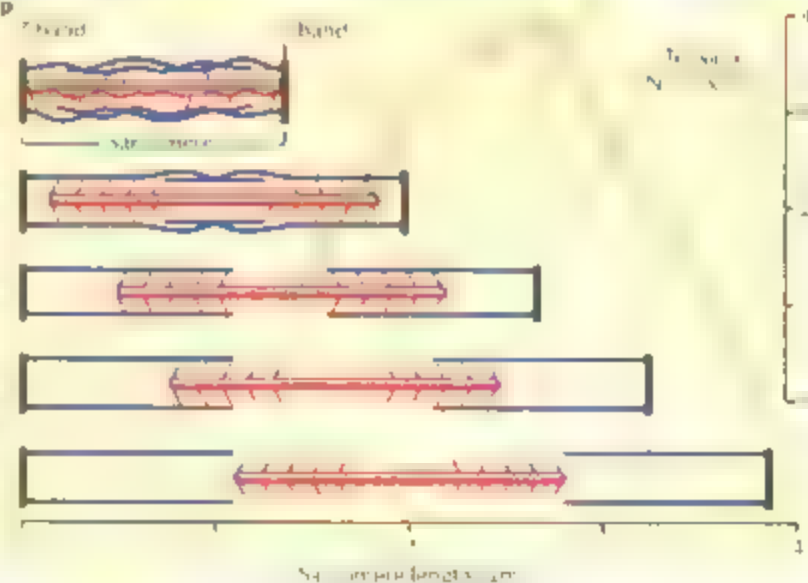


FIGURE 3.6 GRADING OF MUSCLE TENSION AND LENGTH-TENSION RELATIONSHIP

In the upper panel, a motor unit is shown. The motor unit is composed of a single motor neuron and the muscle fibers it innervates. The degree of overlap between Z-lines is shown. The degree of overlap is directly related to the degree of tension. The degree of overlap is directly related to the degree of tension.

As the degree of overlap increases, the tension increases. The degree of overlap is directly related to the degree of tension. The degree of overlap is directly related to the degree of tension.

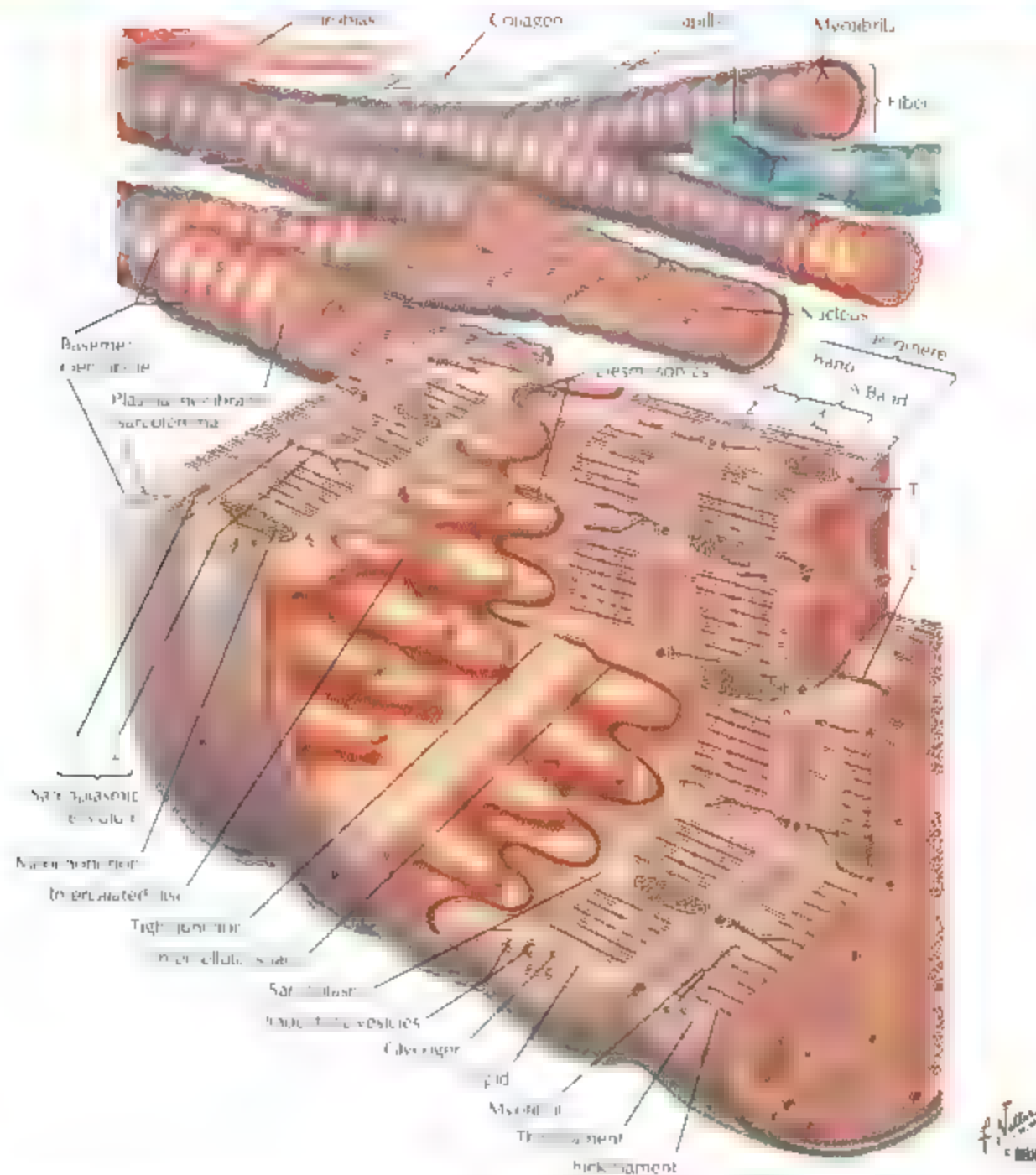


FIGURE 3.7 SCHEMA OF STRUCTURE OF CARDIAC MUSCLE

Cardiac muscle, like skeletal muscle, is striated in appearance, reflecting the presence of the regularly arranged actin and myosin filaments. Cardiac muscle fibers are branched and electrically coupled to one another by gap junctions, which are not found in skeletal muscle. The filaments in the cardiac cell myofibrils contain transverse tubules like skeletal muscle. However, the sarcoplasmic reticulum is not as elaborate as in skeletal muscle, and diads, rather than triads, are formed between T-tubules and sarcoplasmic reticulum. The electrical coupling of cardiac muscle cells is the basis for the spread of the action potential throughout the heart and

cycling. Among intracellular Ca^{2+} levels, the concentration in heart skeletal and cardiac muscle is higher than in skeletal muscle. Skeletal muscle stores Ca^{2+} in the sarcoplasmic reticulum, which releases it in response to changes in extracellular Ca^{2+} . In heart muscle, the sarcoplasmic reticulum stores Ca^{2+} in the sarcoplasmic reticulum, which releases it in response to changes in extracellular Ca^{2+} . The release of Ca^{2+} from the sarcoplasmic reticulum is regulated by the ryanodine receptor, which is a Ca^{2+} -activated Ca^{2+} release channel. The release of Ca^{2+} from the sarcoplasmic reticulum is regulated by the ryanodine receptor, which is a Ca^{2+} -activated Ca^{2+} release channel. The release of Ca^{2+} from the sarcoplasmic reticulum is regulated by the ryanodine receptor, which is a Ca^{2+} -activated Ca^{2+} release channel.

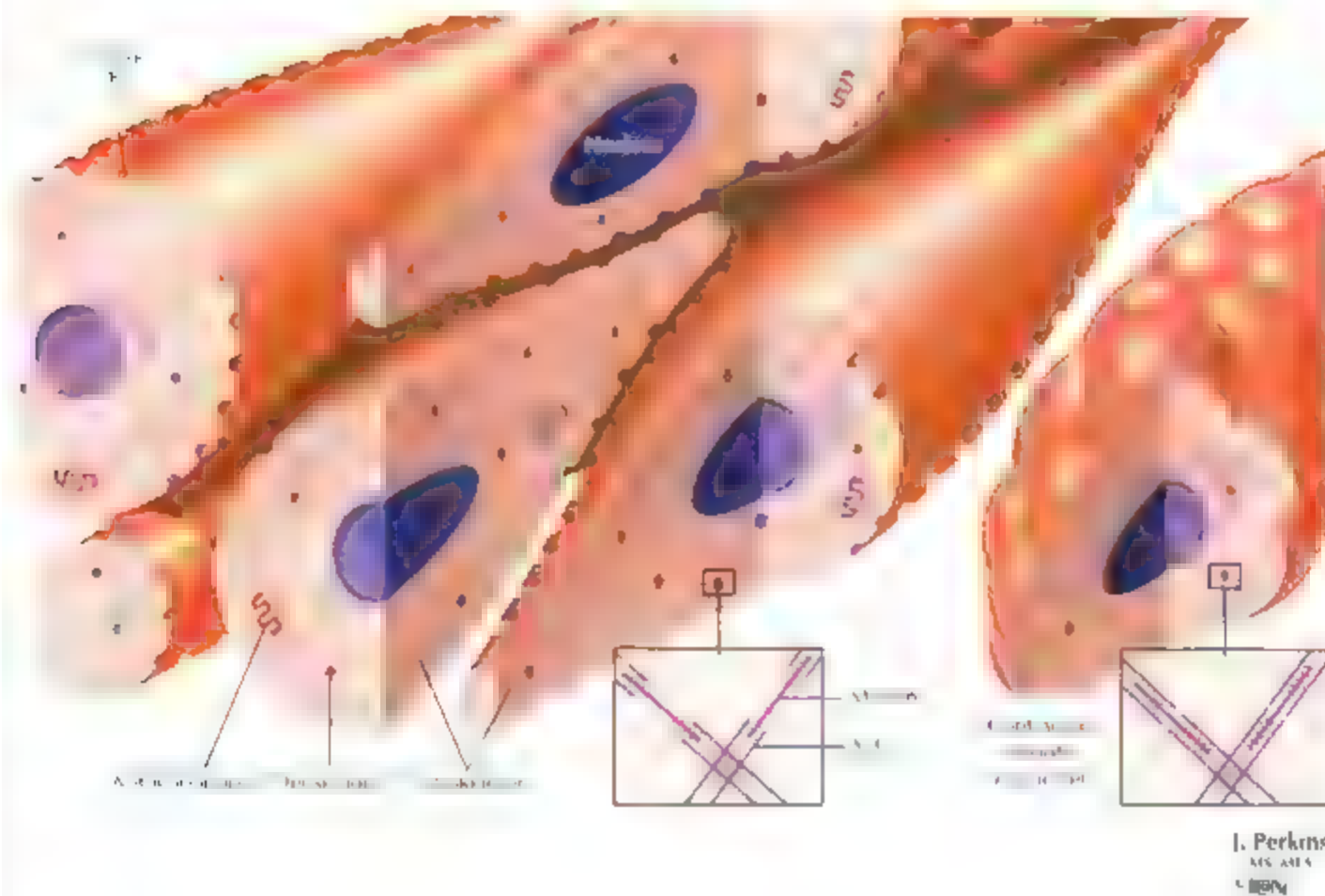


FIGURE 3.8 SMOOTH MUSCLE STRUCTURE

Smooth muscle cells are spindle-shaped and contain a single, centrally located nucleus. The cells are arranged in a somewhat organized pattern with visible cell junctions. The diagram illustrates the arrangement of actin filaments (thin filaments) and myosin filaments (thick filaments) within a cell. The actin filaments are arranged in a network, and the myosin filaments are arranged in a more organized pattern. The diagram also shows the arrangement of the cell membrane and the nucleus.

The diagram illustrates the arrangement of actin filaments (thin filaments) and myosin filaments (thick filaments) within a cell. The actin filaments are arranged in a network, and the myosin filaments are arranged in a more organized pattern. The diagram also shows the arrangement of the cell membrane and the nucleus.

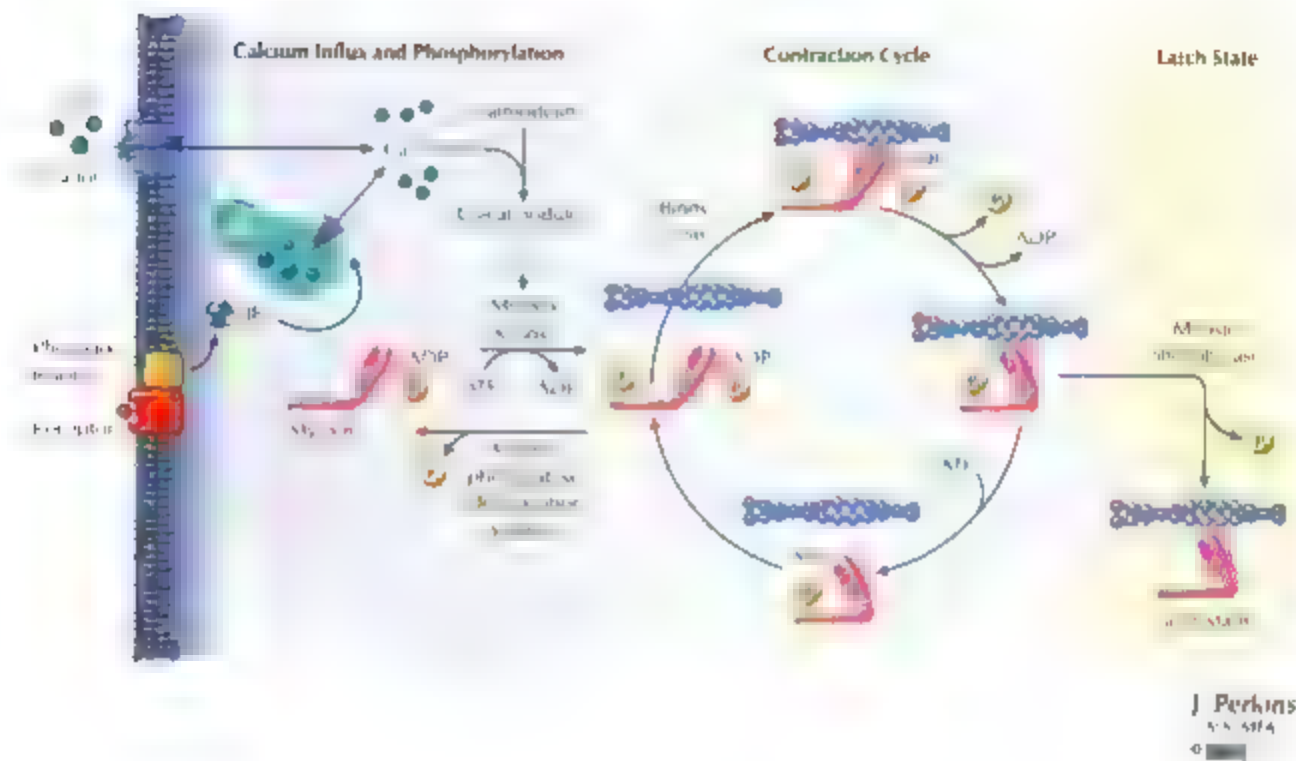


FIGURE 3.9 EXCITATION-CONTRACTION COUPLING OF SMOOTH MUSCLE

In the latch state, the myosin heads remain attached to actin, maintaining tension. This state is regulated by the balance of MLCK and myosin phosphatase (MPP). MPP dephosphorylates the myosin light chain, leading to relaxation. The diagram shows that in the latch state, the myosin is still phosphorylated but the tension is maintained.

telomerase activity is increased in cancer cells. The enzyme is a ribonucleoprotein complex that contains an RNA subunit and a protein subunit. The RNA subunit is essential for the enzyme's activity, and the protein subunit is responsible for the enzyme's specificity. The enzyme is found in all eukaryotic cells, but its activity is highest in stem cells and cancer cells.

TABLE 3.1 COMPARISON OF MUSCLE STRUCTURE AND FUNCTION

	Skeletal Muscle	Cardiac Muscle	Smooth Muscle
Structure			
Morphology	Long, cylindrical	Branches	Spindle or fusiform
Nuclei	Multiple; located peripherally	One (sometimes two); located centrally	One; located centrally
Intercalated disks	Yes; striated pattern	Yes; striated pattern	No
Gap junctions	Yes; forms triad with sarcoplasmic reticulum	Yes; forms dyad with sarcoplasmic reticulum	No; caveolae
Electrical coupling	No	Yes; desmosomes; gap junctions	Yes; gap junctions
Regeneration	Yes; via satellite cells	No	Yes
Autonomic innervation	No	No	Yes
Physiology			
Extracellular Ca^{2+} required for contraction	No	Yes	Yes
Regulation of cross-bridge formation	Ca^{2+} binding to troponin	Ca^{2+} binding to troponin	Ca^{2+} calmodulin-dependent protein kinase and phosphorylation of myosin
Control of contraction	Motor neurons	Autonomic nerves, β -adrenergic agonists	Autonomic nerves, hormones
Summation of twitches by increased stimulus frequency	Yes	No	Yes
Tetanus via tetanic stimulation	Yes	Yes	Yes

NOTE: The structure and function of skeletal, cardiac, and smooth muscle are indicated.

Abbreviations: Ca^{2+} , calcium; Ca^{2+} calmodulin-dependent protein kinase, Ca^{2+} calmodulin-dependent protein kinase; β -adrenergic agonists, β -adrenergic agonists; β -adrenergic agonists, β -adrenergic agonists.

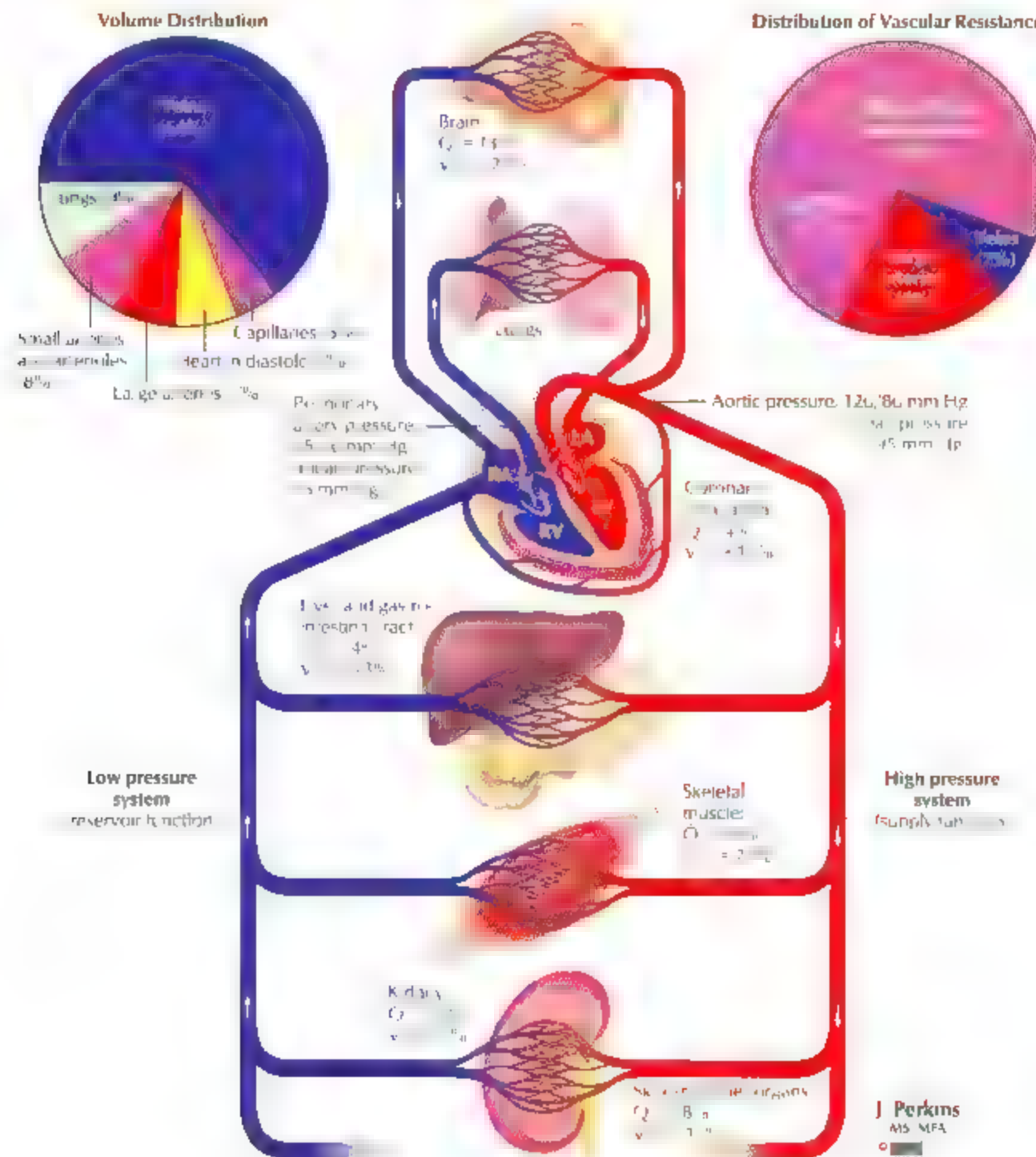


FIGURE 4.1 CARDIOVASCULAR SYSTEM OVERVIEW

The cardiovascular system consists of the heart, which pumps blood into the pulmonary circulation for the exchange of O_2 and CO_2 and into the systemic circulation to supply all other tissues of the body. A resting cardiac output is approximately 5 L/min in both the pulmonary and systemic circulations. The amount of blood flow (Q) as a percentage of cardiac output, and relative percentage of oxygen utilization, are plotted for various organs systems shown in the

accompanying table. The systemic circulation is composed of a parallel branching organ, heart, gastrointestinal tract, etc. Based on metabolic needs, the heart can increase its flow to 2 L/min and the gastrointestinal tract can increase its flow to 1.5 L/min. At any one time, most of the blood volume resides in the veins (64%) and is returned to the right side of the heart. Vascular resistance is primarily a function of the small muscular arteries and arterioles.

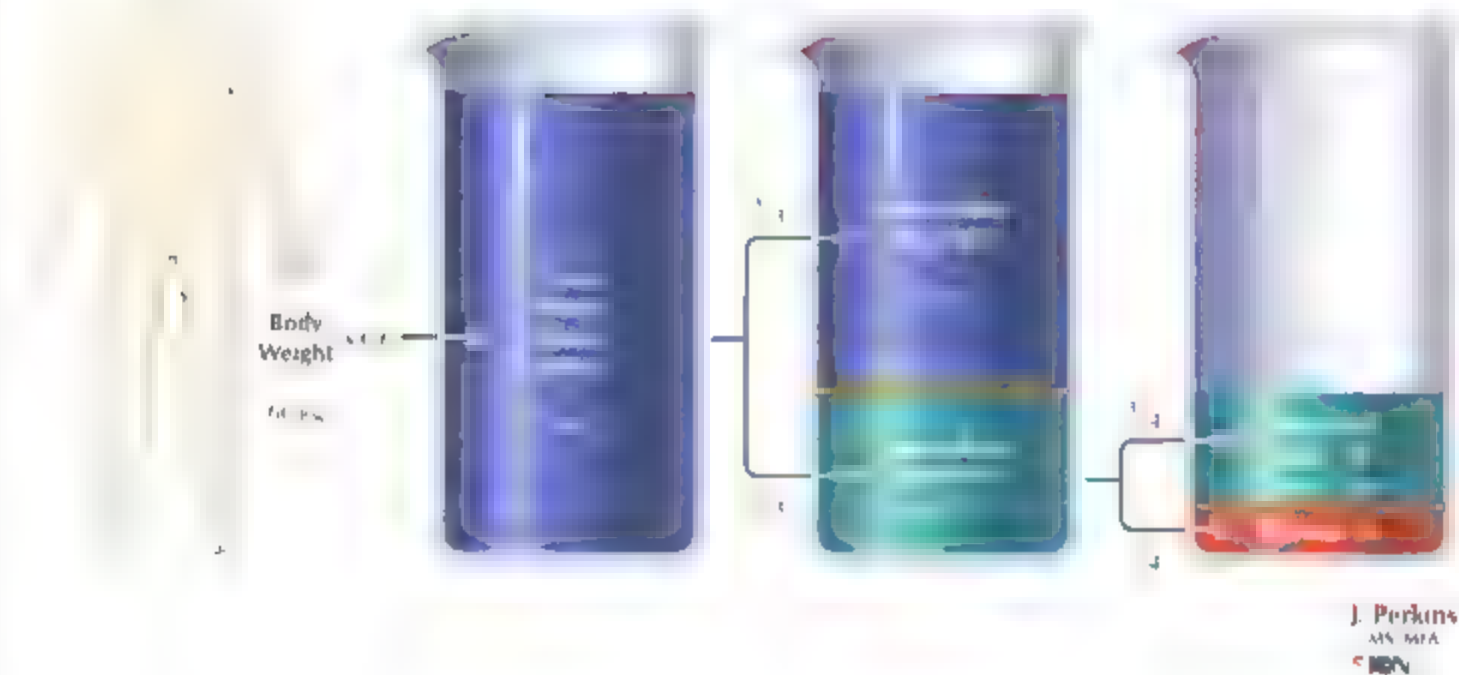


FIGURE 4.2 BODY FLUID COMPARTMENTS

body water (about 42 L or 70% of body weight). The intracellular fluid (ICF) is the fluid inside the cells, and the extracellular fluid (ECF) is the fluid outside the cells. The plasma volume is the fluid in the blood vessels.

fluid of plasma within blood vessels and interstitial fluid. The interstitial fluid is the fluid between the cells, and the plasma is the fluid in the blood vessels. The plasma volume is the fluid in the blood vessels.

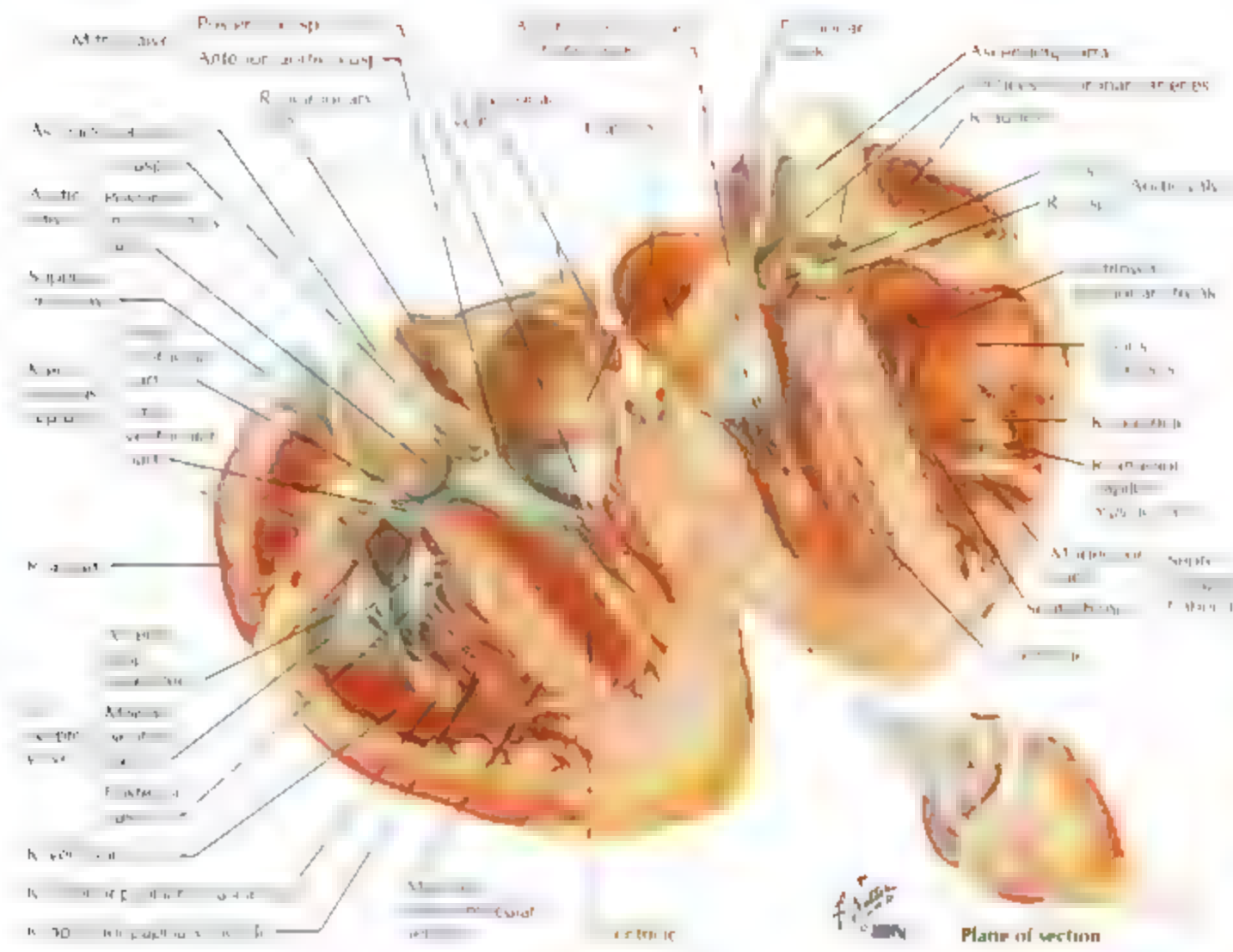
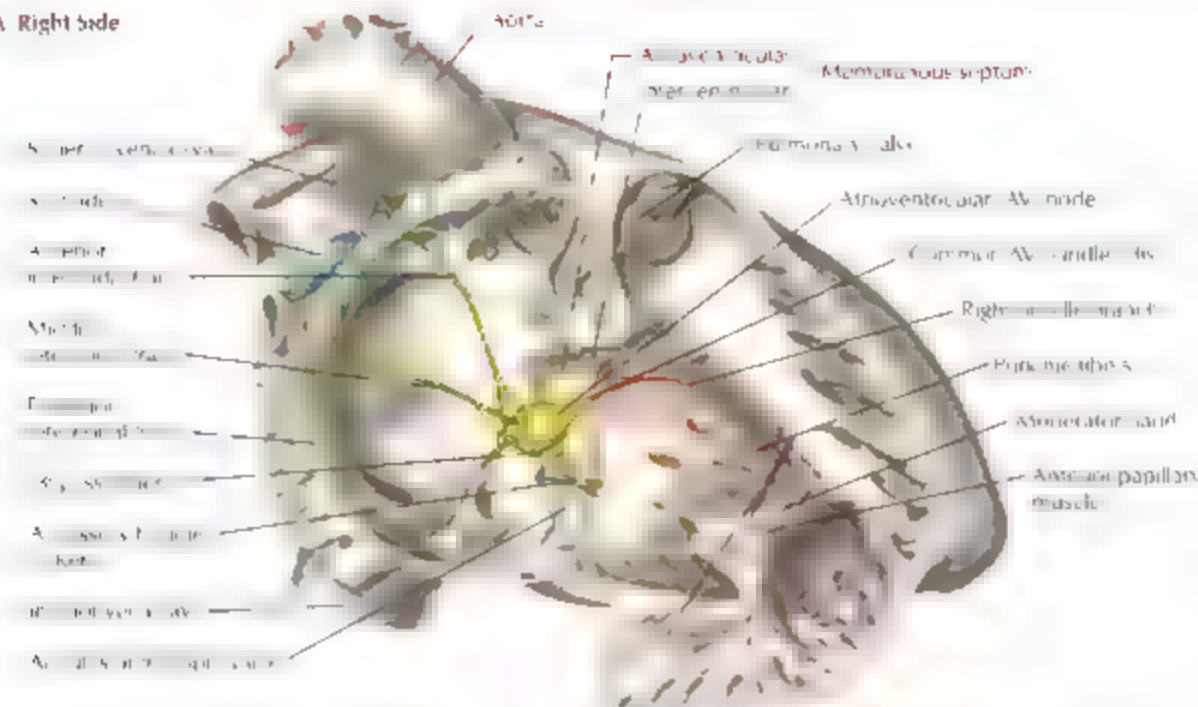


FIGURE 4.3 STRUCTURE OF HEART

This diagram shows the heart in cross-section, illustrating the four chambers (right and left atria and ventricles) and the major blood vessels (superior and inferior vena cava, pulmonary artery, and aorta). The heart is located in the thoracic cavity, and its position is shown relative to the diaphragm. The diagram also shows the pericardium, which is the protective sac surrounding the heart. A small inset shows a cross-section of the heart wall, labeled 'Plane of section'.

and pumps blood to the rest of the body. The work of the heart is to pump blood to the rest of the body, and the heart is the only organ that can pump blood to itself. The heart is a muscular organ, and its walls are made of muscle tissue. The heart is also a vascular organ, and it has a network of blood vessels that supply it with oxygen and nutrients. The heart is also a regulatory organ, and it can adjust its pumping rate to meet the needs of the body. The heart is a complex organ, and its structure is highly specialized for its function.

A. Right Side



B. Left Side

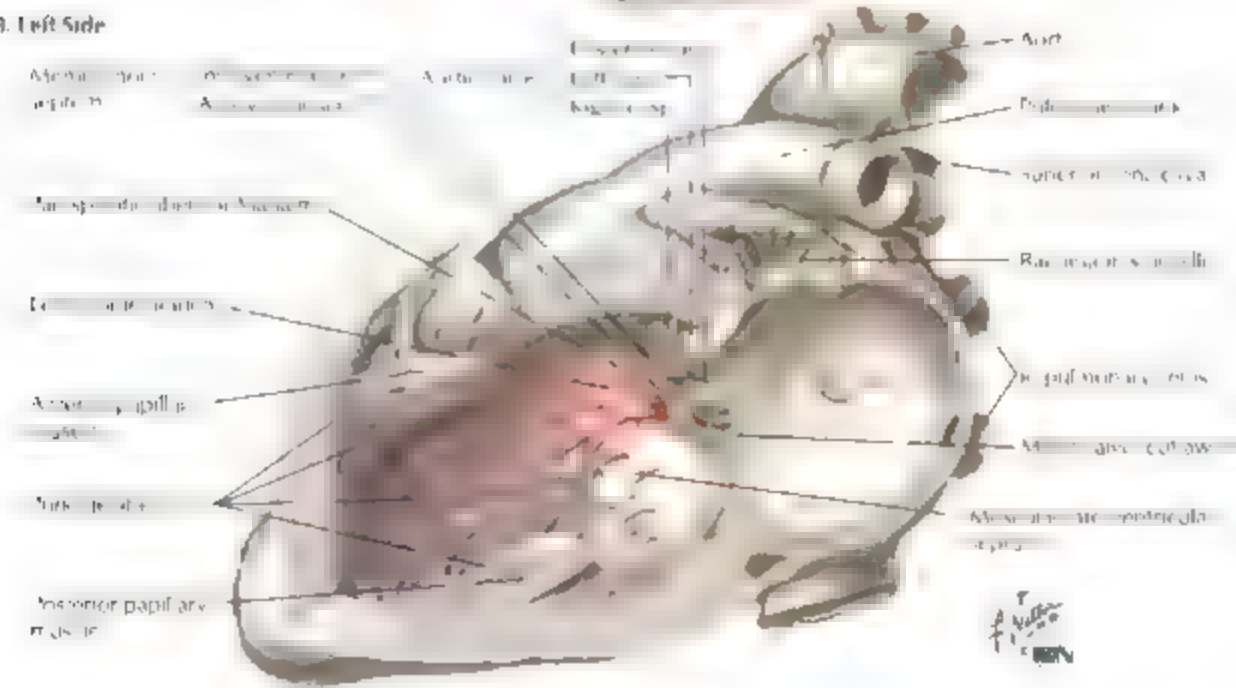


FIGURE 4.4 ANATOMY OF THE SPECIALIZED CONDUCTION SYSTEM

The specialized conduction system of the heart is responsible for the generation and propagation of the electrical impulse that initiates each heartbeat. The system consists of the sinoatrial (SA) node, atrioventricular (AV) node, bundle of His, bundle branches, and Purkinje fibers. The SA node is located in the right atrium and is the primary pacemaker of the heart. The AV node is located in the septum between the atria and ventricles and acts as a delay station for the electrical impulse. The bundle of His is located in the septum and gives rise to the bundle branches, which carry the impulse to the Purkinje fibers. The Purkinje fibers are located in the walls of the ventricles and are responsible for the rapid depolarization that leads to contraction.

The electrical impulse is generated by the SA node and travels through the atria to the AV node. From the AV node, the impulse travels through the bundle of His and the bundle branches to the Purkinje fibers. The Purkinje fibers are located in the walls of the ventricles and are responsible for the rapid depolarization that leads to contraction. The entire conduction system is embedded in the heart muscle and is surrounded by a network of blood vessels.

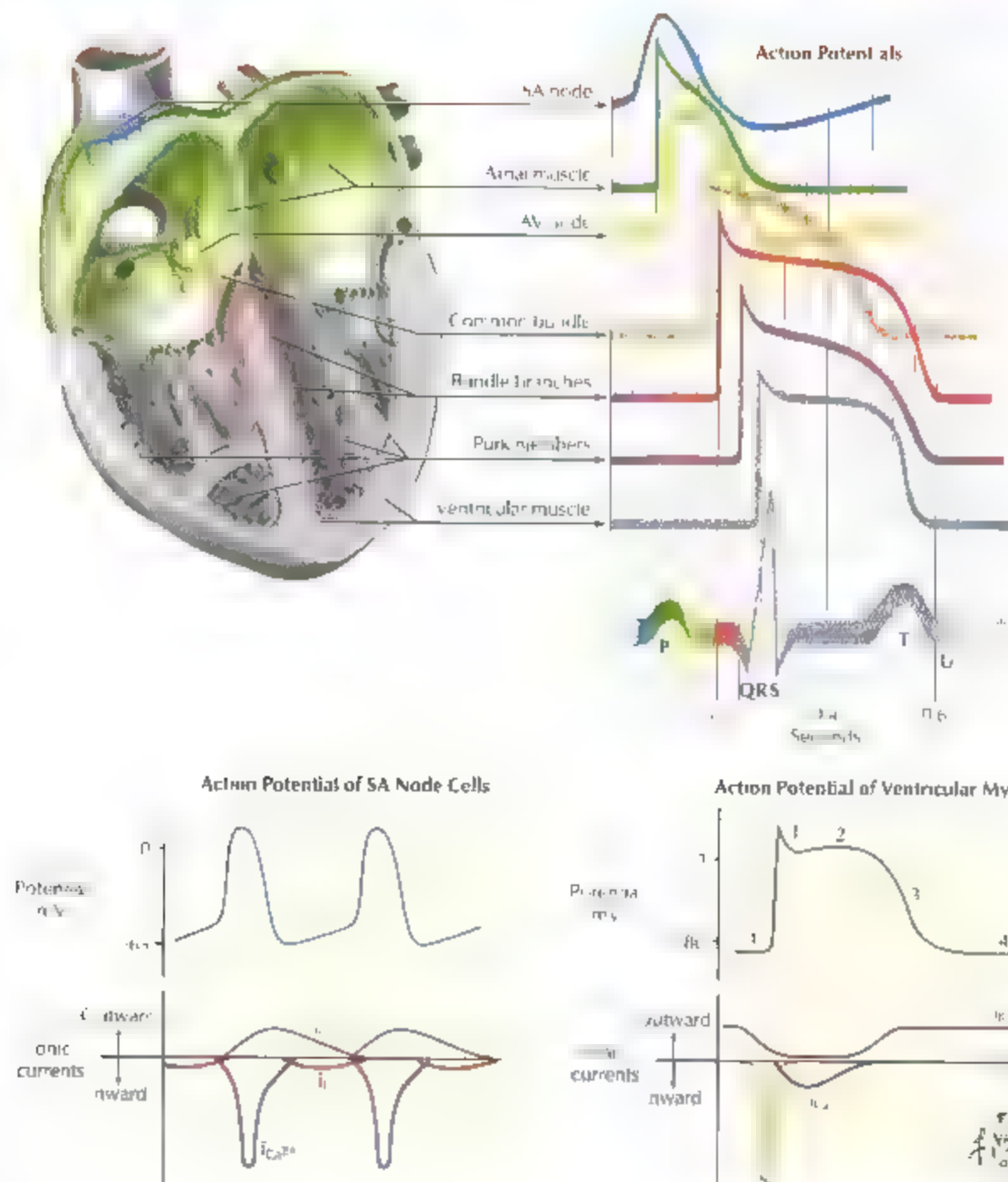


FIGURE 4.5 ELECTRICAL ACTIVITY OF THE HEART

The normal pumping of blood through the chambers of the heart requires the precisely timed spread of action potentials through the heart's conduction system and the atrial and ventricular muscle. The rate of the heart beat is set by spontaneously generated action potentials in the cells of the SA node. The frequency of SA node action potentials is regulated by the autonomic nervous system. Sympathetic stimulation of the SA node increases I_f (principally Na^+ current

and I_H) which depolarizes the cell and directly increases the rate. Parasympathetic stimulation increases I_A which hyperpolarizes the cell and thereby decreases the heart rate. The ventricular action potential has a prolonged depolarization phase resulting from Ca^{2+} influx. This long plateau phase prevents the any cell from being able to fire again until the plateau phase has ended.

Normal Sequence of Cardiac Depolarization and Repolarization and Derivation of ECG

A. Impulse origin and atrial depolarization

Impulse originates in SA node and spreads rapidly over the atria, causing depolarization of the atria. This is represented by the P wave on the ECG. The QRS complex represents ventricular depolarization, and the T wave represents ventricular repolarization.

Atrial

Impulse originates in SA node and spreads rapidly over the atria, causing depolarization of the atria. This is represented by the P wave on the ECG. The QRS complex represents ventricular depolarization, and the T wave represents ventricular repolarization.

B. Septal depolarization

Impulse spreads rapidly over the atria, causing depolarization of the atria. This is represented by the P wave on the ECG. The QRS complex represents ventricular depolarization, and the T wave represents ventricular repolarization.

Impulse spreads rapidly over the atria, causing depolarization of the atria. This is represented by the P wave on the ECG. The QRS complex represents ventricular depolarization, and the T wave represents ventricular repolarization.

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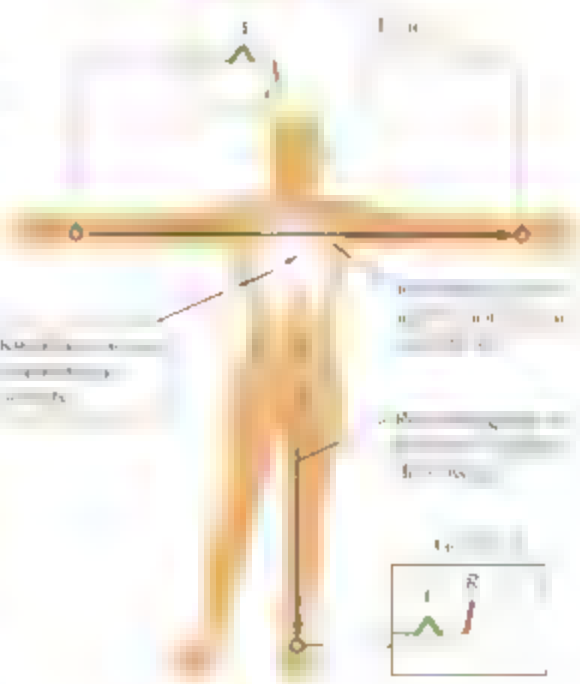
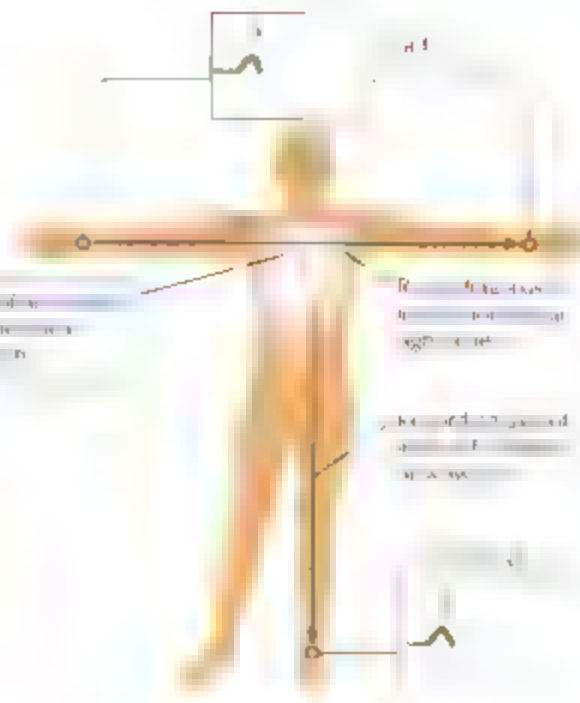


FIGURE 4.6 CARDIAC DEPOLARIZATION AND REPOLARIZATION PART 1

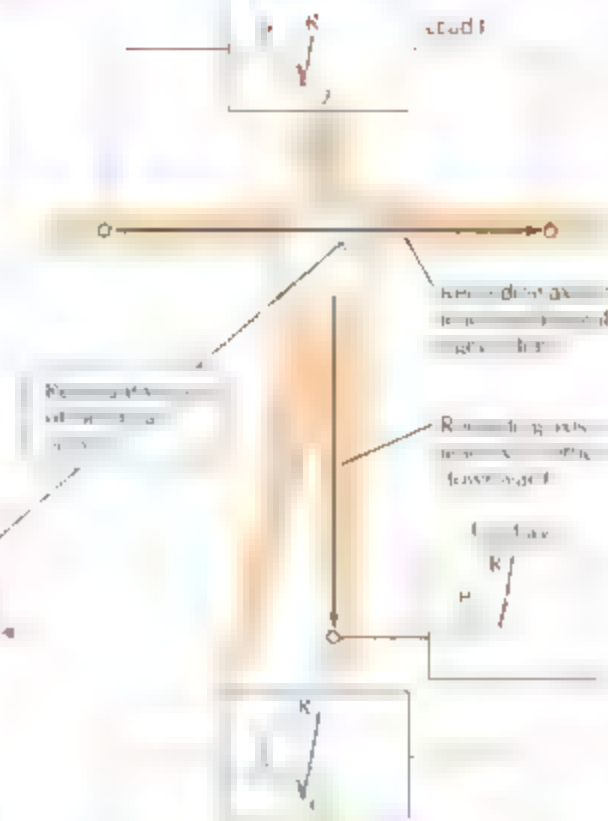
The sequence of cardiac depolarization and repolarization is shown in the figure. The P wave represents atrial depolarization, the QRS complex represents ventricular depolarization, and the T wave represents ventricular repolarization. The sequence of cardiac depolarization and repolarization is shown in the figure.

The sequence of cardiac depolarization and repolarization is shown in the figure. The P wave represents atrial depolarization, the QRS complex represents ventricular depolarization, and the T wave represents ventricular repolarization. The sequence of cardiac depolarization and repolarization is shown in the figure.

Normal Sequence of Cardiac Depolarization and Repolarization and Derivation of ECG (continued)

C. Apical and early ventricular depolarization

Impulse continues along endocardial system causing depolarization of apical and basal septum and early ventricular depolarization. This results in a small upward deflection (K wave) if the lead is oriented toward the apex.



D. Late ventricular depolarization

As the impulse reaches the base of the ventricle, the depolarization wave spreads through the septum and the base of the ventricle. This results in a large upward deflection (R wave) if the lead is oriented toward the base.

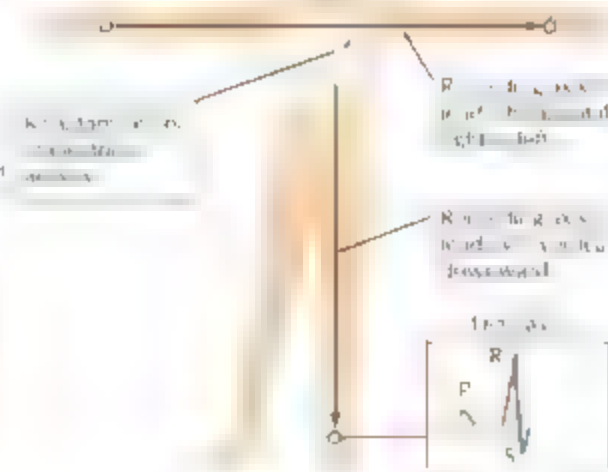
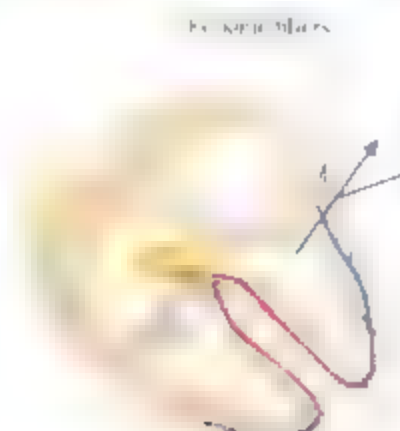


FIGURE 4.7 CARDIAC DEPOLARIZATION AND REPOLARIZATION PART 2

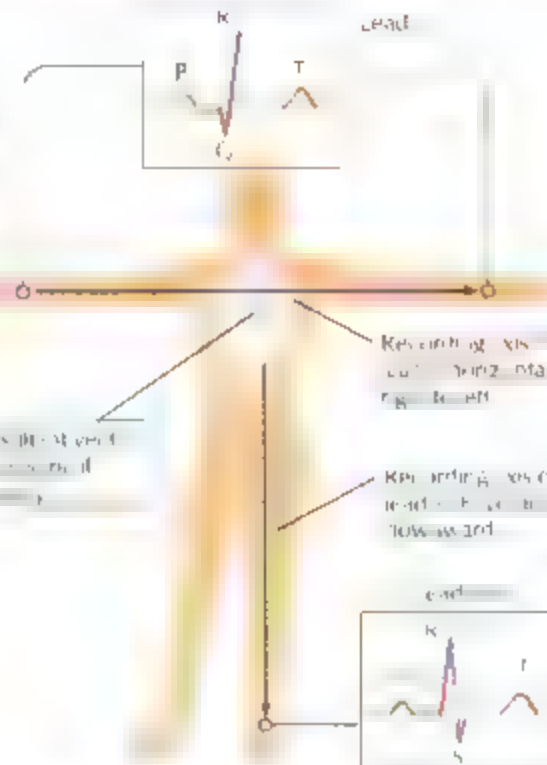
ECG tracing. As the apex of the ventricle contracts a large upward deflection of the tracing yields the R wave on the ECG paper. Then the wave of depolarization spreads through

the posterior wall, causing the S wave of the ECG tracing.

Normal Sequence of Cardiac Depolarization and Repolarization and Derivation of ECG (continued)

E Repolarization

When the heart is fully depolarized, there is no electrical activity for brief period (ST segment). Then, repolarization begins from endocardium (inner wall) moving toward epicardium (outer wall) directed downward and to the left, giving rise to a negative deflection in both leads I and aVL. A period of no electrical activity follows as the K⁺ channels close and the next impulse originates at SA node.



F Summary of cardiac electrical activity

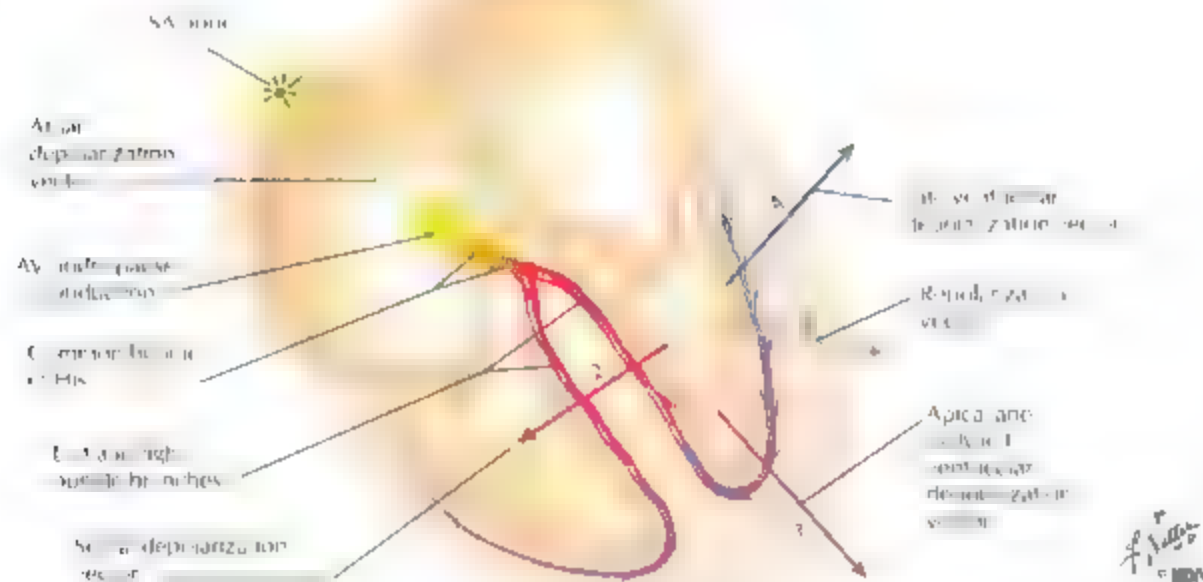


FIGURE 4.8 CARDIAC DEPOLARIZATION AND REPOLARIZATION PART 3

ECG continues. Once fully depolarized, electrical activity passes briefly into ST segment of the tracing, and then repolarization begins, moving from the inner endocardium to the outer epicardium

generating the T wave of the ECG tracing shown in Figure 4.8. The repolarization sequence events only occur after the depolarization.

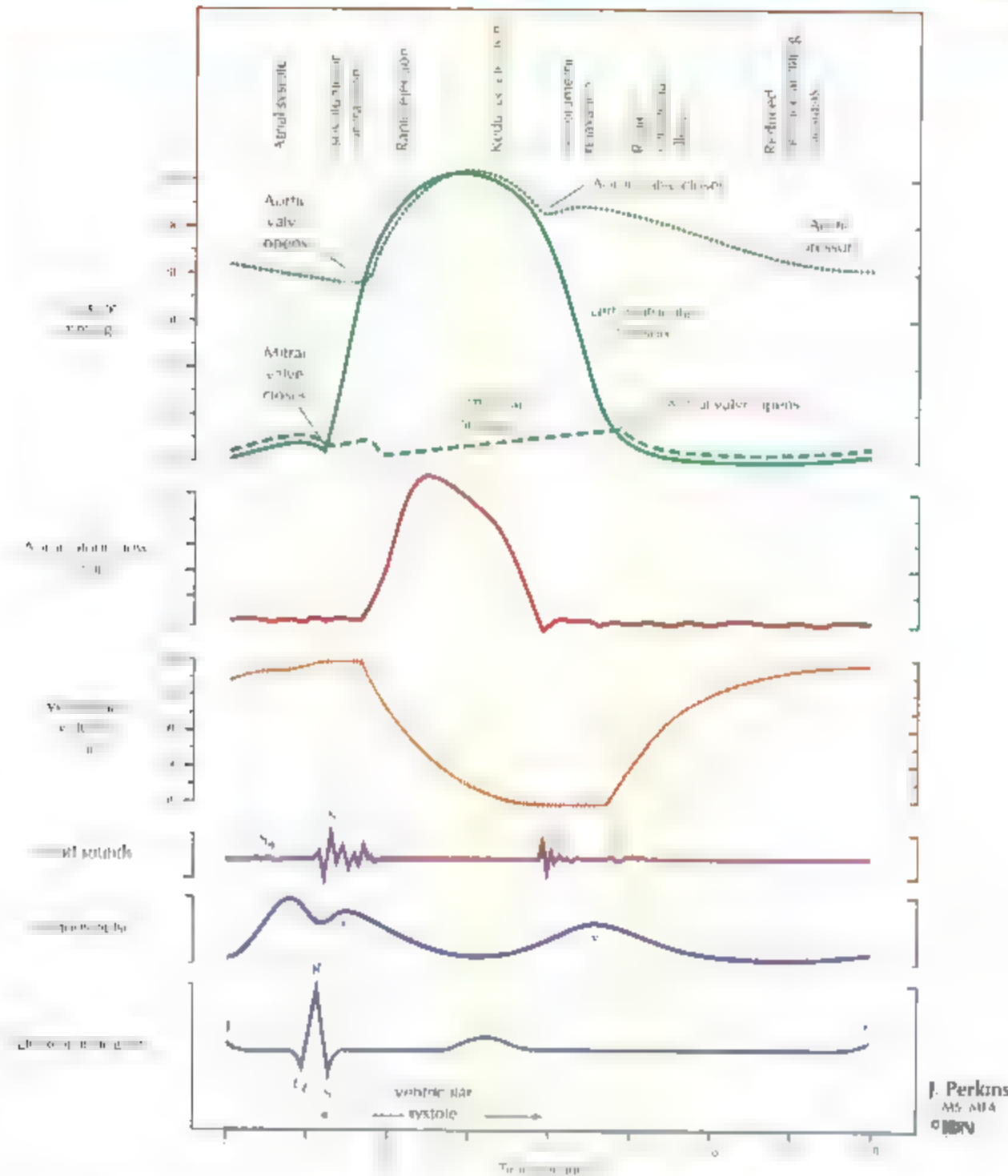


FIGURE 4.9 CARDIAC CYCLE

The cardiac cycle represents one complete sequence of atrial and ventricular contraction and relaxation. It includes the electrical and hemodynamic events associated with a single cycle. Changes in left atrial pressure, left ventricular pressure, and aortic pressure, stroke volume, heart sounds, jugular venous pressure, and the ECG are known. The S₁ heart sound results from closure of the atrioventricular cuspal valves, while the S₂ heart sound results from closure of the aortic and pulmonary valves. Both S₁ and S₂ are sounds associated with filling of the ventricles. They are normally difficult to hear in

healthy adults. S₃ is heard in healthy children and in some adults. It is associated with the rapid deceleration of blood flow during early diastole. The components of the jugular venous pulse—the a wave, which is the atrial contraction wave, and the v wave, which results from bulging of the tricuspid valve into the right atrium during right ventricular contraction, are the waves resulting from the right atrial pressure. The waves of the jugular venous pulse are the result of the atrial pressure changes during the cardiac cycle. The components of the ECG are described in Figures 4.6 and 4.3.

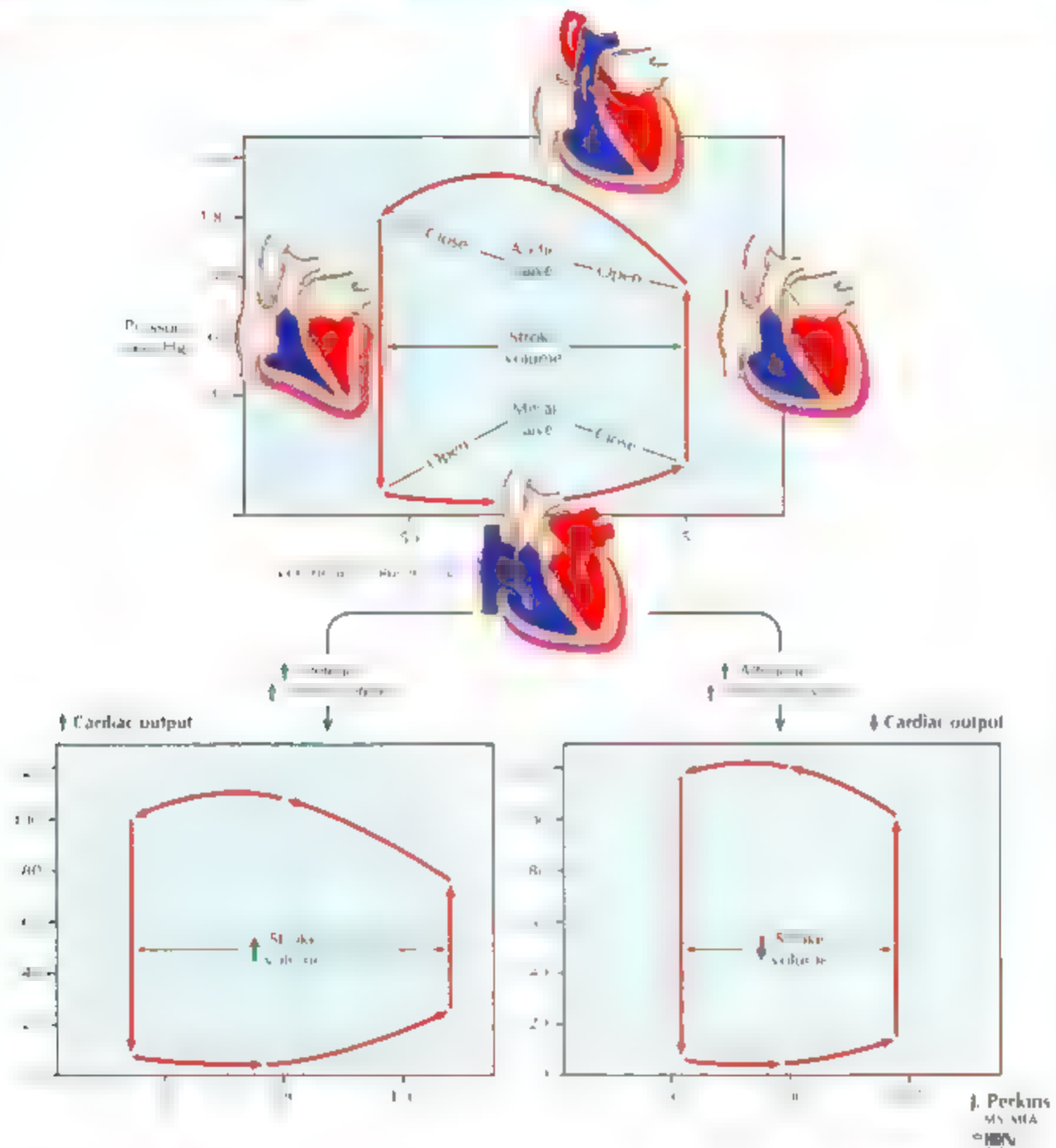


FIGURE 4-10 PRESSURE-VOLUME LOOP

Cardiac output is the volume of blood pumped by the heart per minute. It is calculated by multiplying the stroke volume (the volume of blood pumped by the heart per beat) by the heart rate (the number of beats per minute). The pressure-volume loop is a graph that shows the relationship between pressure and volume in the heart.

$$\text{Cardiac output} = \text{Stroke volume} \times \text{Heart rate}$$

where

$$\text{Stroke volume} = \text{End-diastolic volume} - \text{End-systolic volume}$$

Increases in stroke volume increase cardiac output. Increases in heart rate also increase cardiac output. However, if the pressure in the arteries is too high, the heart cannot pump as much blood, and cardiac output decreases.

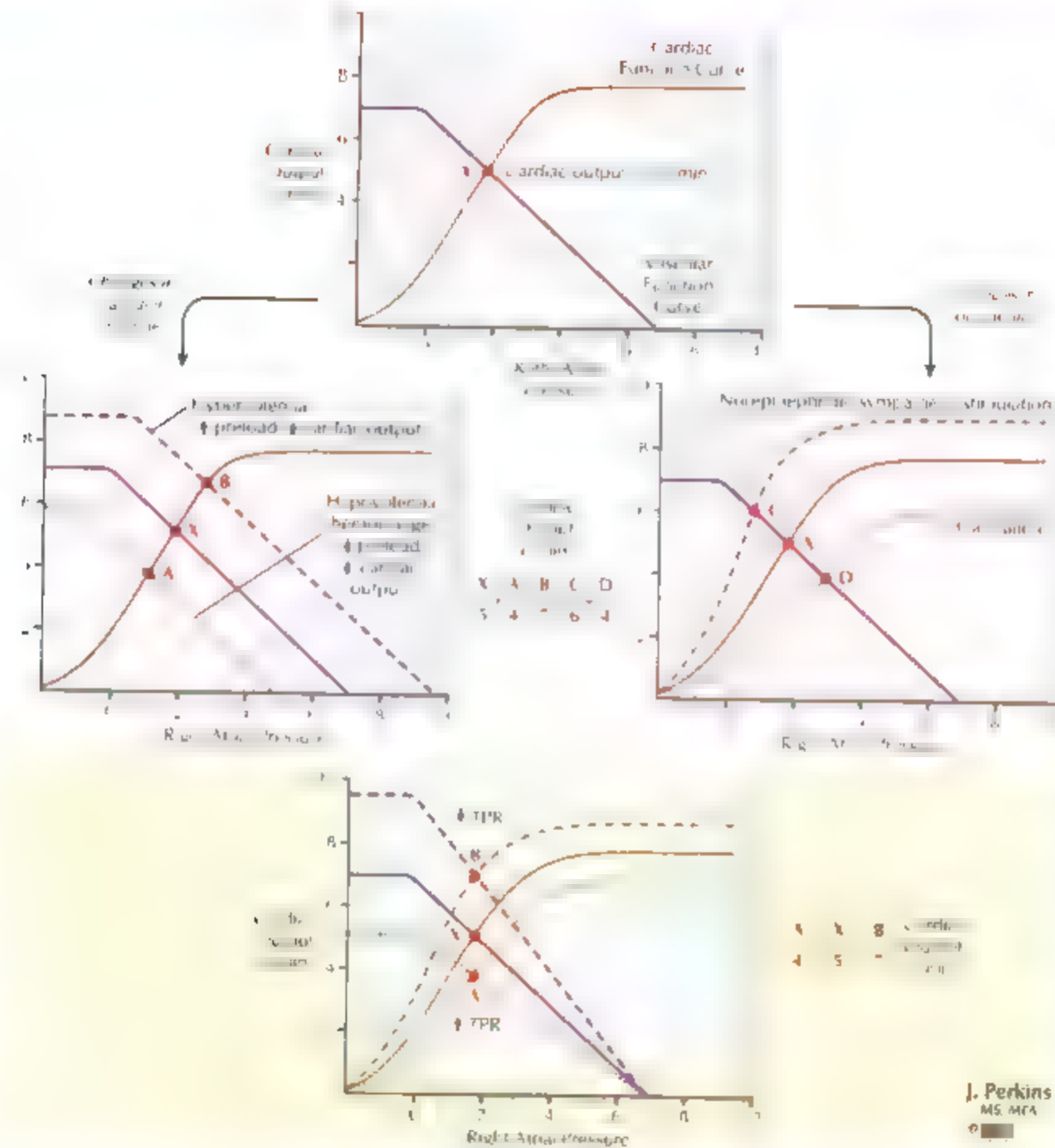


FIGURE 4.11 CARDIAC AND VASCULAR FUNCTION CURVES

The heart and blood vessels interact with each other in determining cardiac output. Depicted in the series of graphs are the cardiac function curves and the vascular resistance curves. The graphs illustrate the changes in right atrial pressure and cardiac output in response to changes in venous return, peripheral resistance, and arterial pressure.

Cardiac function curves and vascular resistance curves are used to determine the relationship between cardiac output and right atrial pressure. The graphs illustrate the changes in right atrial pressure and cardiac output in response to changes in venous return, peripheral resistance, and arterial pressure.

J. Perkins
MS, MPA

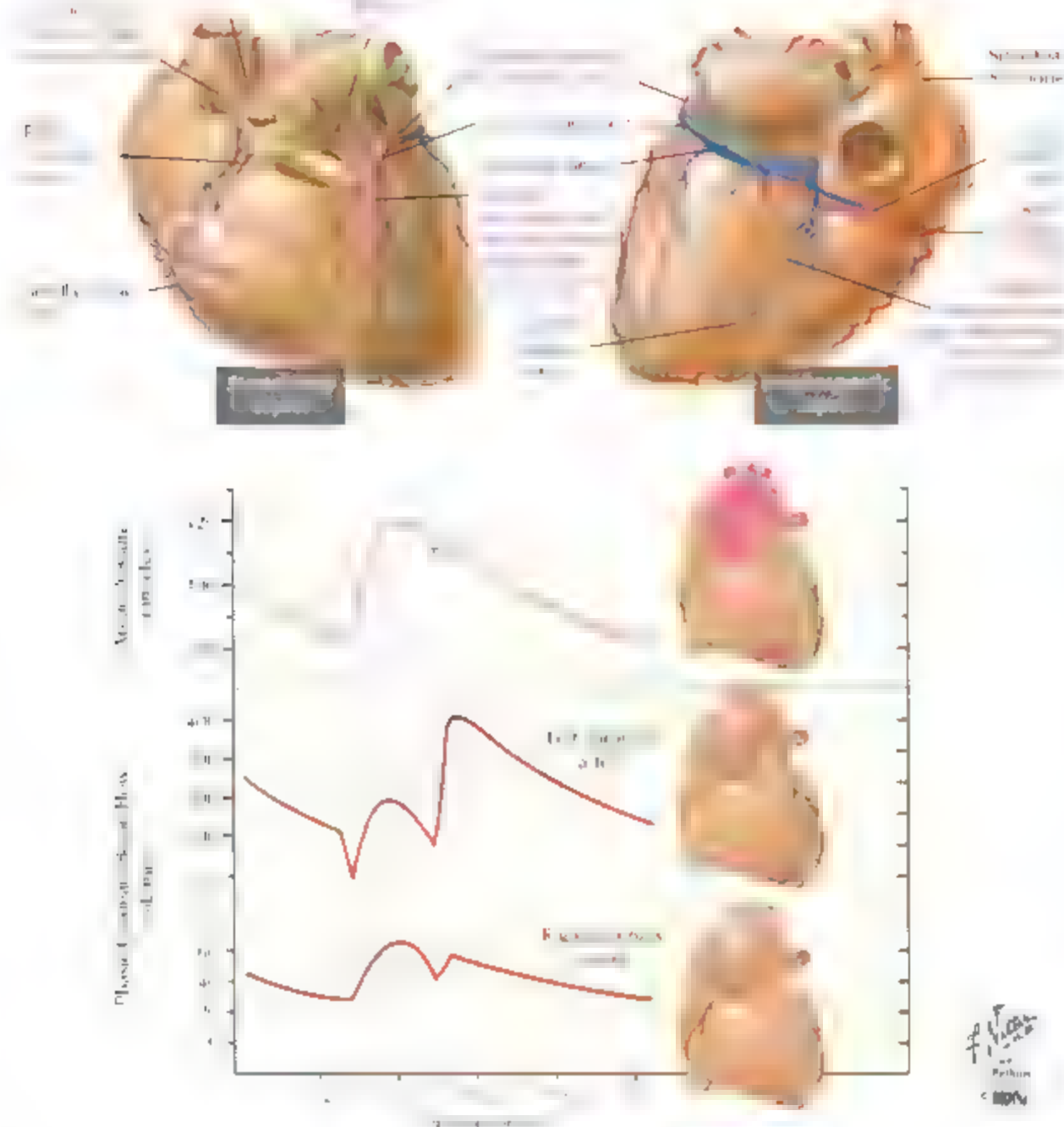
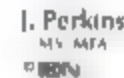


FIGURE 4.12 CORONARY CIRCULATION

The coronary circulation is the primary source of oxygen and nutrients for the heart muscle. It is a high-flow, high-pressure system that is highly responsive to changes in myocardial oxygen demand. The coronary arteries branch out from the base of the heart, supplying the myocardium with blood. The coronary veins collect deoxygenated blood from the myocardium and return it to the right atrium of the heart. The coronary circulation is a critical component of the cardiovascular system, and its function is essential for the heart to pump blood effectively.

[illegible][illegible]



The Δ is a useful measure. MAP is about one-third of the sum of the systolic pressure, is determined by the stroke volume (SV) and the total peripheral resistance (TPR) as $MAP = (CO \times TPR) \div SV$ (see Figure 1). CO is determined by the stroke volume (SV) and heart rate (HR) as $CO = SV \times HR$. Blood flow in the aorta is identical to the SV. The stroke volume is a systemically controlled parameter (see Figure 1). To determine the stroke volume, SV, a patient

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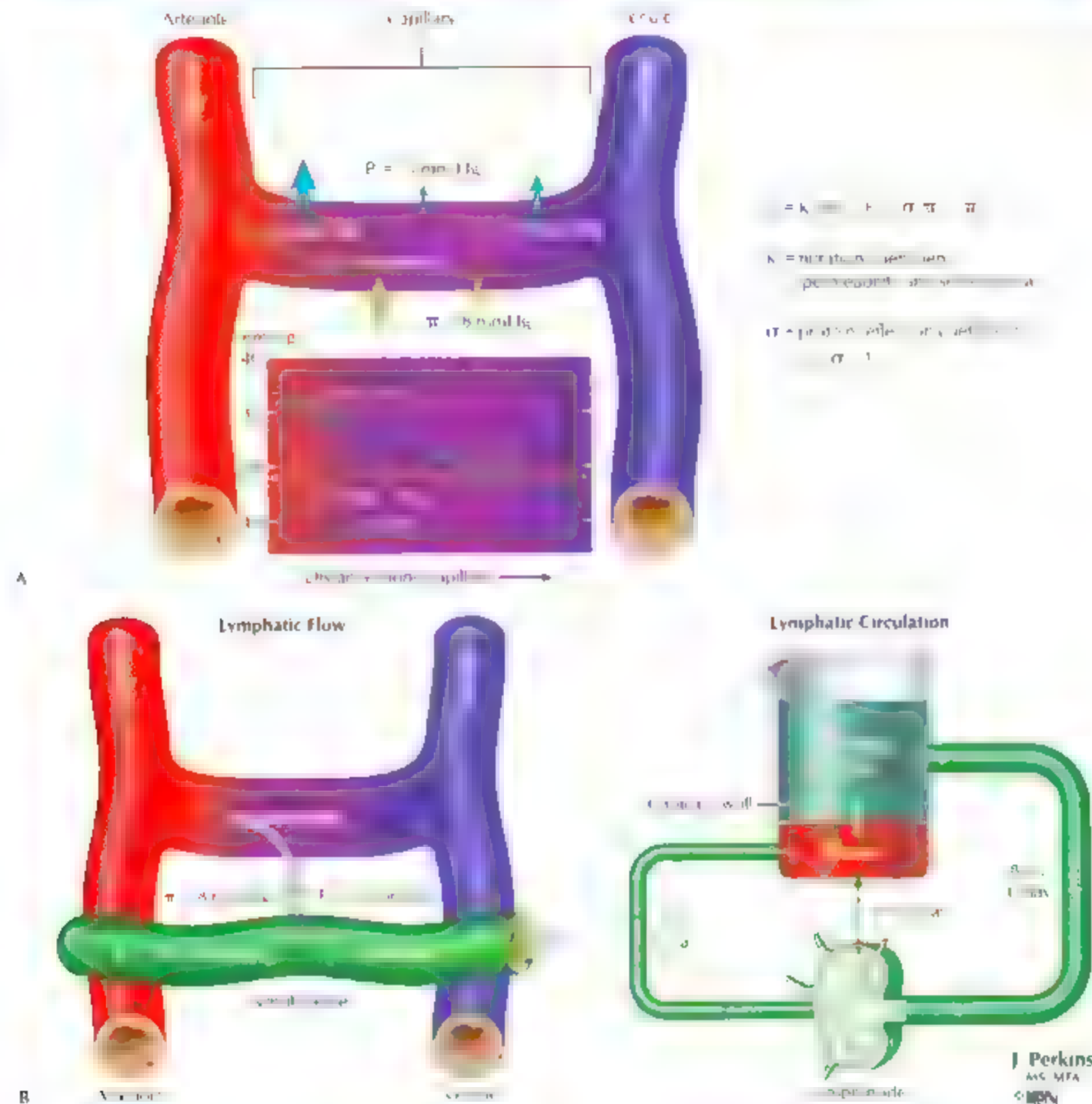


FIGURE 4.16 MICROCIRCULATION

Endothelial cells are highly metabolically active and are the primary site for the production of nitric oxide (NO). NO is a potent vasodilator and is produced by the endothelial cells in response to shear stress. The production of NO is regulated by the endothelial nitric oxide synthase (eNOS) enzyme. eNOS is a transmembrane protein that is activated by shear stress and produces NO from L-arginine and NADPH. NO then diffuses into the smooth muscle cells and causes them to relax, leading to vasodilation. This process is essential for maintaining blood flow and pressure in the microcirculation.

Smooth muscle cells (SMCs) are also highly metabolically active and are the primary site for the production of angiotensin II (Ang II). Ang II is a potent vasoconstrictor and is produced by the SMCs in response to angiotensin I (Ang I). Ang I is converted to Ang II by the angiotensin-converting enzyme (ACE). Ang II then binds to receptors on the SMCs, causing them to contract and leading to vasoconstriction. This process is essential for maintaining blood flow and pressure in the microcirculation.

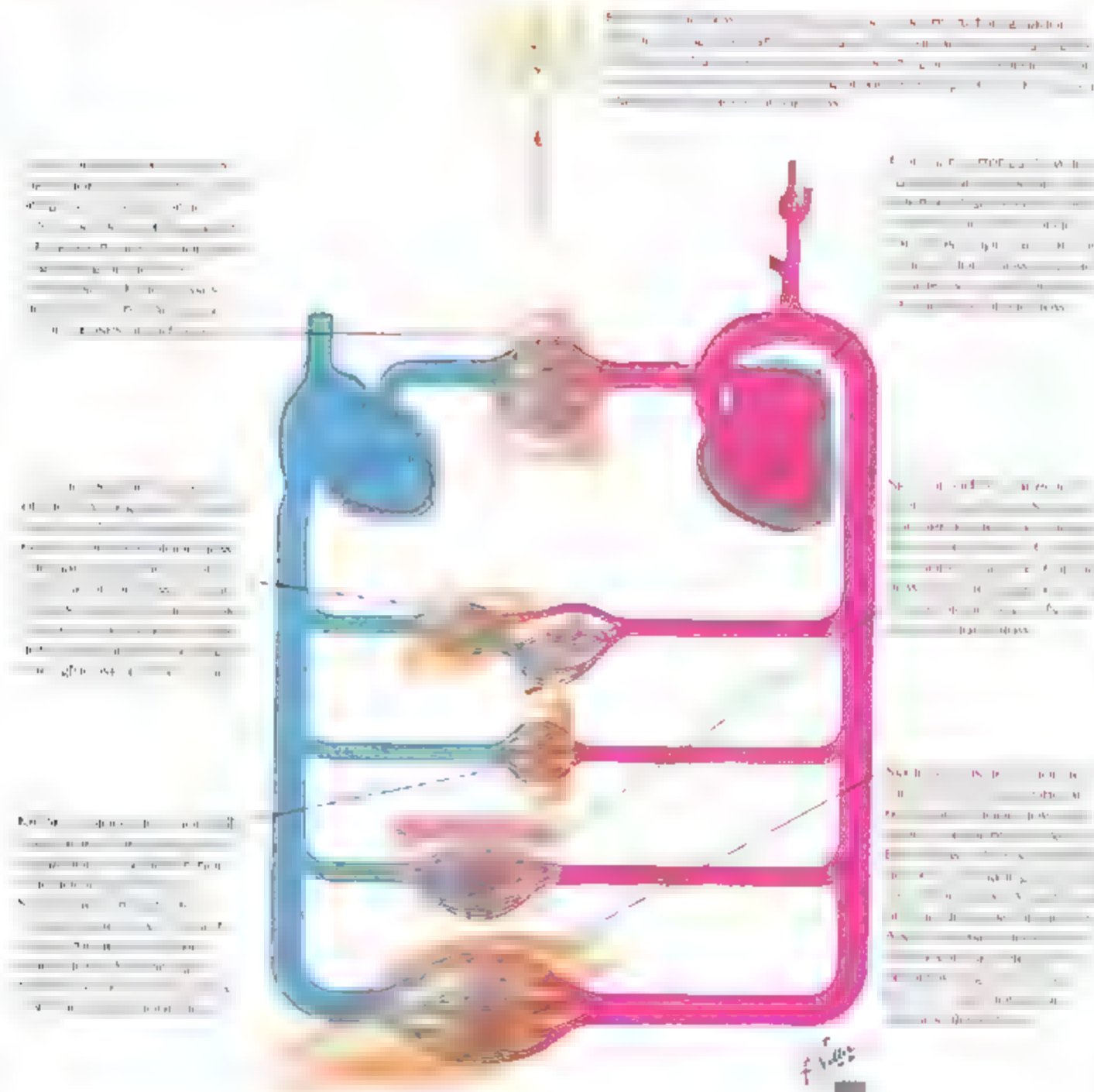


FIGURE 4.17 CIRCULATION TO SPECIAL REGIONS

Diagram illustrating the circulation to special regions, showing the heart, lungs, and various organs with their respective blood supply and drainage.

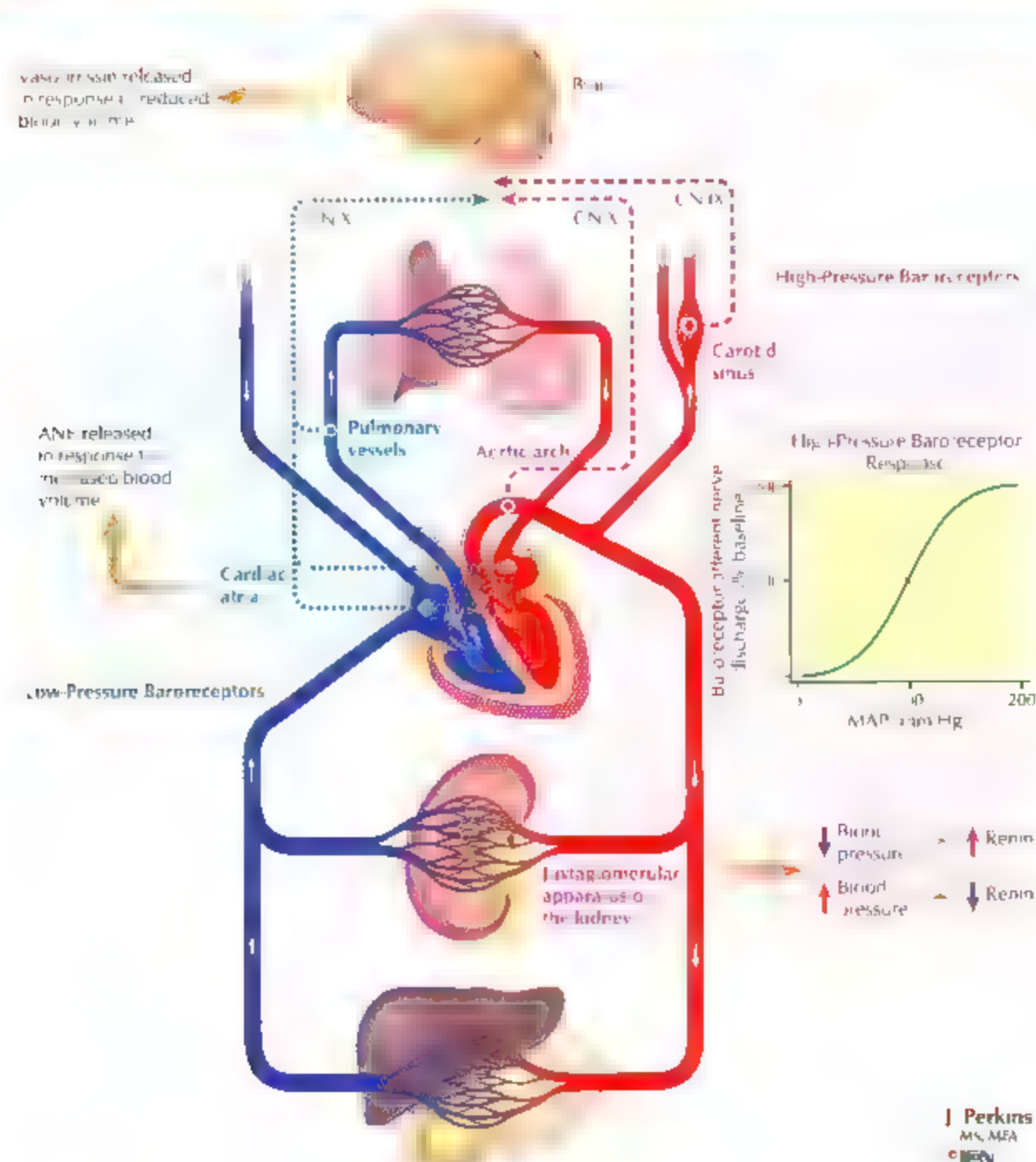


FIGURE 4.18 MONITORING OF BLOOD PRESSURE

The body uses a complex system to monitor and regulate blood pressure. The system is critically important for the maintenance of BP during everyday life—e.g., rising from a sitting to a standing position or exercise—as well as during abnormal conditions—e.g., excessive heat in a hot environment or hemorrhage. Pressure sensors, called “baroreceptors,” are located in the high-pressure (arterial) and low-pressure (venous) sides of the circulatory system. High-pressure receptors in the aortic arch and carotid sinus monitor arterial BP. Aortic signals in the brainstem in the vagus (CN X) and glossopharyngeal (CN IX) nerves. These signals result in alterations in sympathetic activity (not shown). The afferent arterioles of the juxtaglomerular apparatus are also high-pressure baroreceptors. The vasopressin is

released in arterial BP by varying the secretion.

the proteolytic enzyme renin. As described in Figure 6.12, renin results in the production of angiotensin II, a potent vasoconstrictor (see Figure 4.5). Low-pressure baroreceptors are found in the large pulmonary vessels and the atria of the heart. By their location, they respond primarily to changes in blood volume. These baroreceptors send signals to the brain in the vagus nerve (CN X), which, in addition to altering sympathetic nerve activity, cause the release of vasopressin (ADH). When stretched (i.e., increased blood volume), the atria also secrete the hormone atrial natriuretic peptide (ANP), which causes the excretion of NaCl and water by the kidneys (see Figure 4.20) and decreases arterial tone (see Figure 4.15).

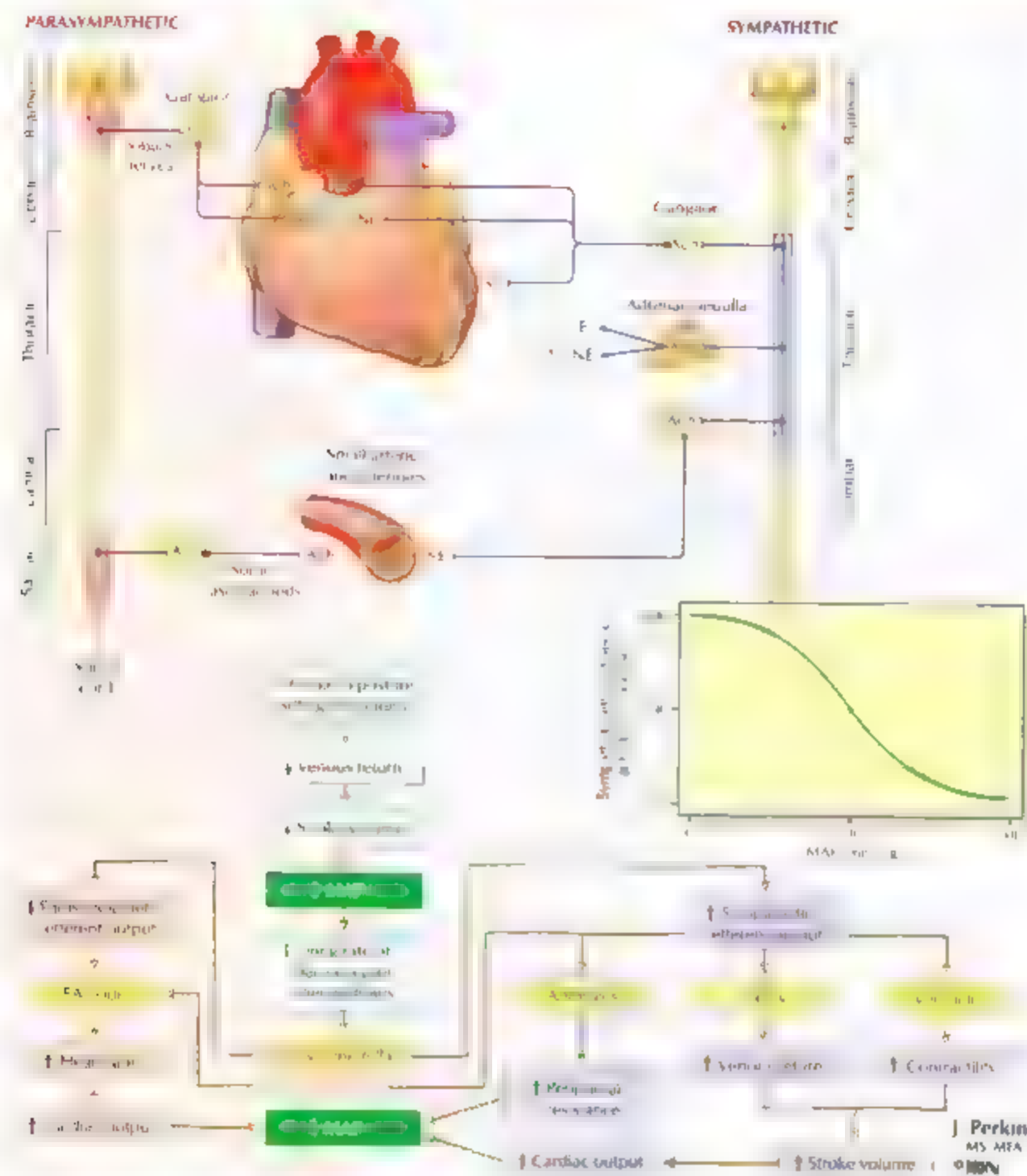
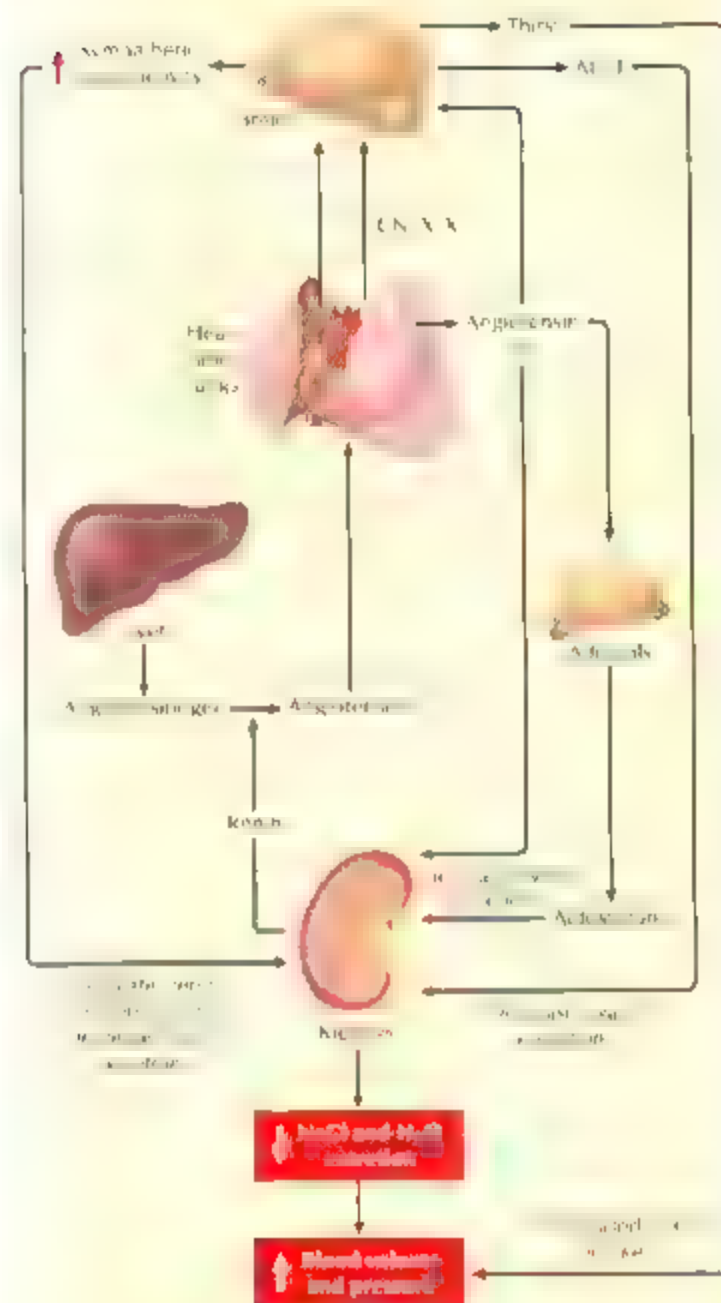


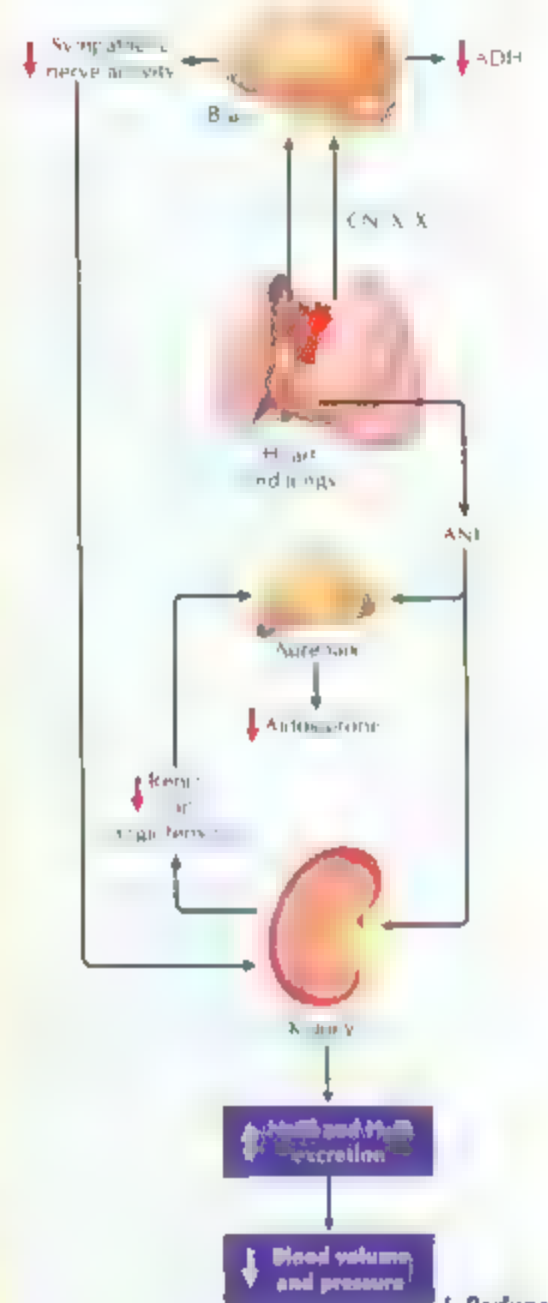
FIGURE 4.19 SHORT-TERM RESPONSE TO CHANGES IN BLOOD PRESSURE

The autonomic nervous system is primarily involved in short-term regulation of blood pressure. A decrease in arterial pressure, as illustrated in Figure 4.19, is detected by baroreceptors in the carotid sinuses and aortic arch. This leads to a decrease in vagal output and an increase in sympathetic output. The sympathetic output also leads to an increase in stroke volume and contractility. The combined effect is an increase in cardiac output, which helps to restore arterial pressure.

Response to Decreased Blood Volume and Pressure



Response to Increased Blood Volume and Pressure



J. Perkins
MS MFA
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FIGURE 4.20 LONG-TERM RESPONSE TO CHANGES IN BLOOD VOLUME AND PRESSURE

When blood volume and pressure changes, the kidneys respond by retaining NaCl and water or excreting NaCl and water in order to return blood volume to its normal value. A further cascade of sympathetic nerve activity, norepinephrine, and epinephrine secretion by the adrenal medulla will be stimulated in this way. The secreted norepinephrine and epinephrine will also stimulate the kidneys to reduce NaCl excretion.

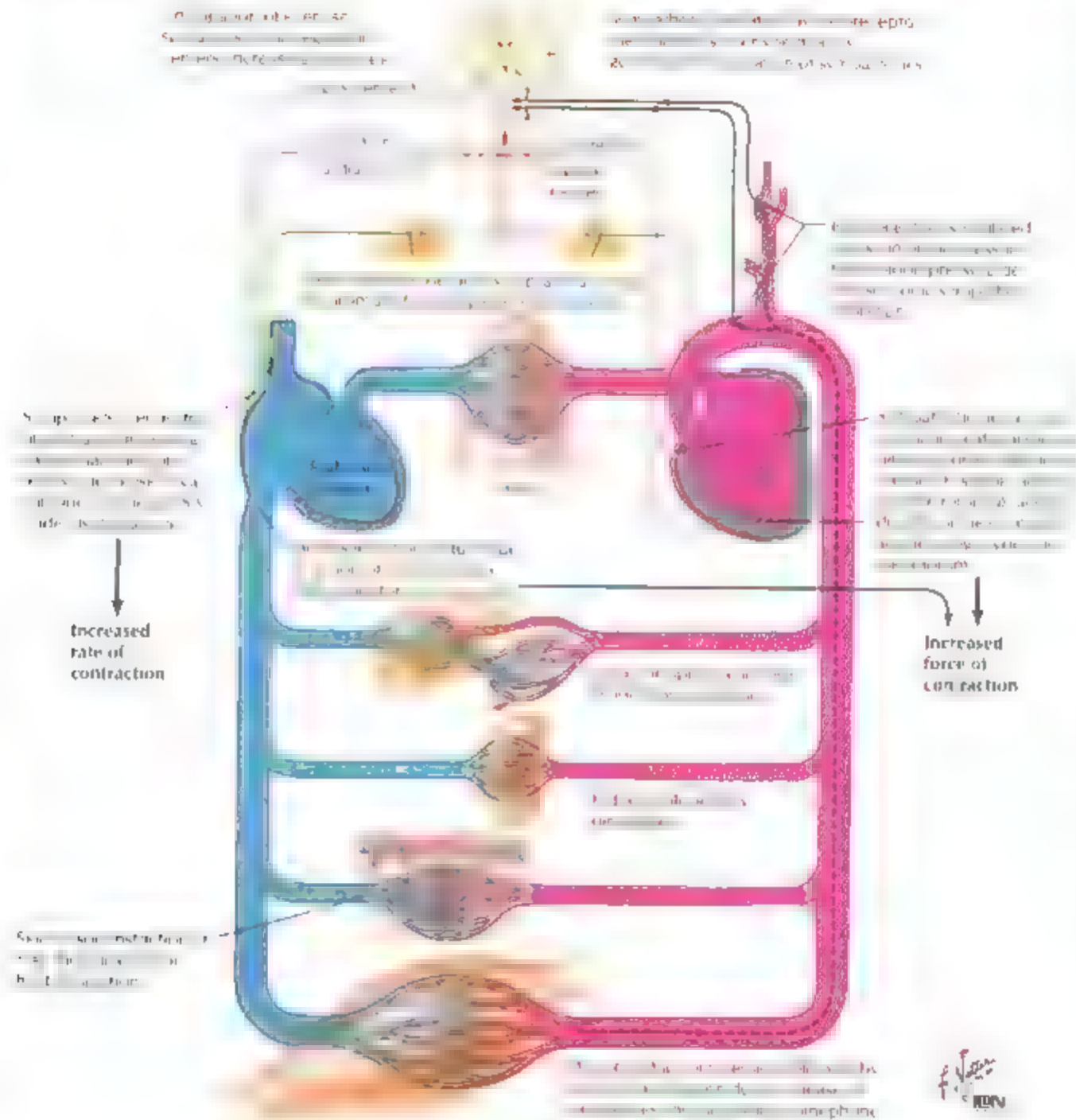


FIGURE 4.21 CIRCULATORY RESPONSE TO EXERCISE

This diagram summarizes the integrated response of the cardiovascular system to exercise. The heart rate and force of contraction increase, leading to an increase in cardiac output. The systemic pressure also increases, leading to an increase in the force of contraction of the systemic circulation.

The diagram also shows the release of chemical mediators such as epinephrine and norepinephrine from the adrenal medulla and sympathetic nerve terminals. These mediators act on the heart and blood vessels to increase heart rate and force of contraction.

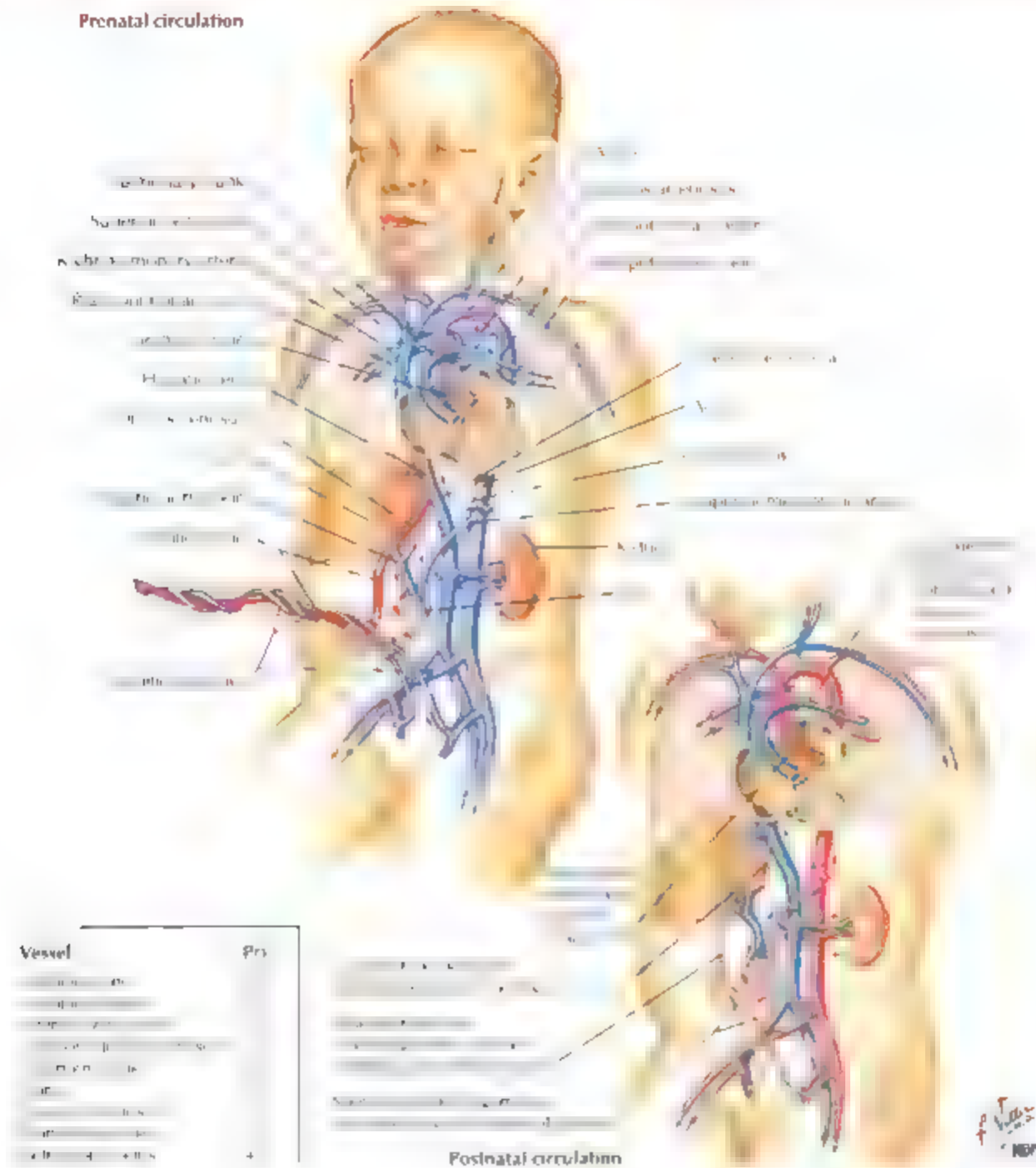


FIGURE 4.22 PRENATAL AND POSTNATAL CIRCULATION

The prenatal circulation is characterized by the presence of the foramen ovale and the ductus arteriosus, which allow blood to bypass the non-functional lungs. After birth, the lungs become functional, and the foramen ovale and ductus arteriosus close, resulting in the postnatal circulation. The postnatal circulation is characterized by the presence of the pulmonary circulation and the systemic circulation. The pulmonary circulation is responsible for oxygenating the blood, and the systemic circulation is responsible for delivering oxygenated blood to the rest of the body.

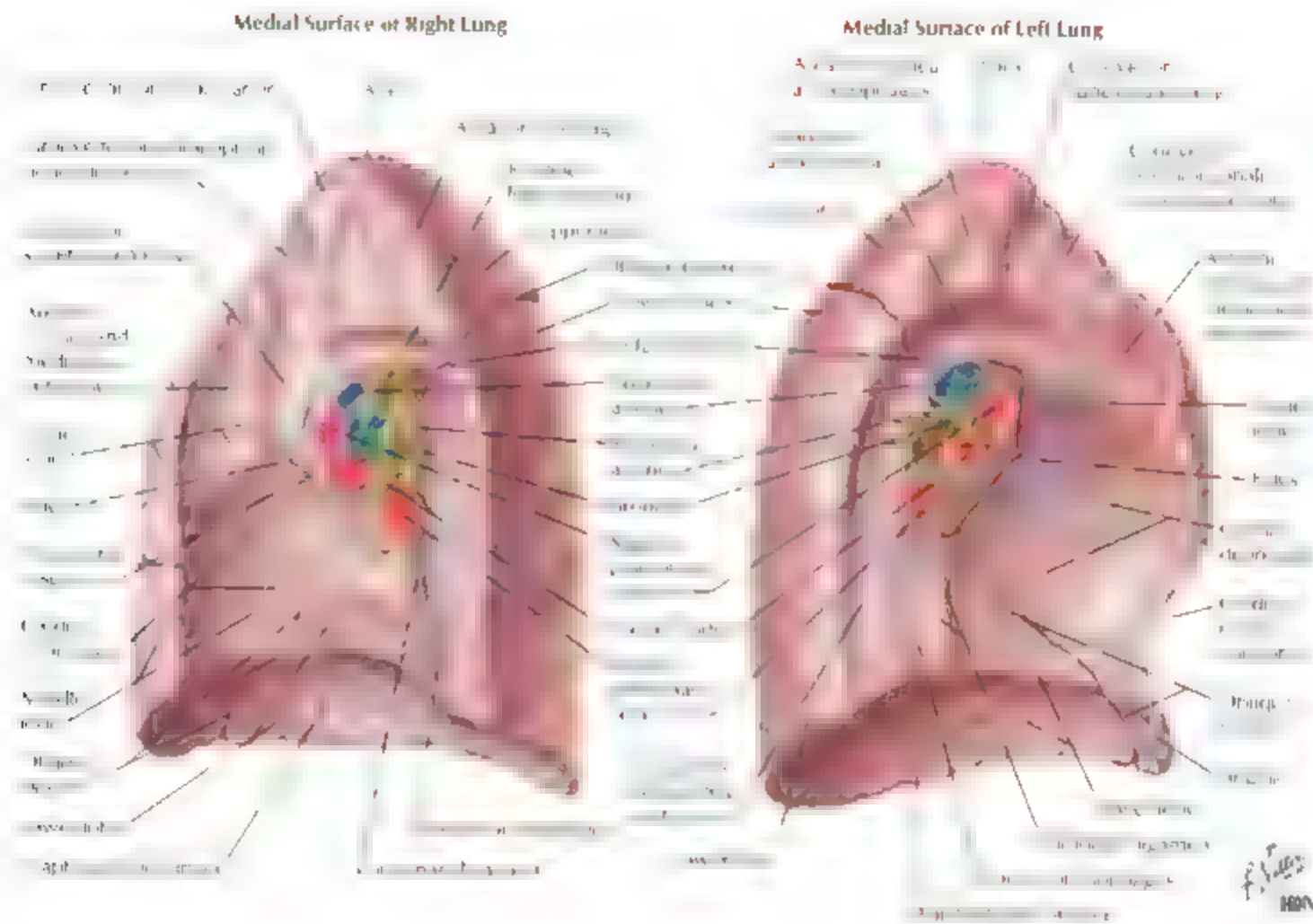


FIGURE 5.1 MEDIAL SURFACE OF THE LUNGS

The medial surface of the lungs shows the heart and major vessels. The right lung is larger than the left lung, and the left lung is smaller. The right lung is divided into three lobes, and the left lung is divided into two lobes. The right lung is also divided into three segments, and the left lung is divided into two segments. The right lung is also divided into three segments, and the left lung is divided into two segments.

The medial surface of the lungs shows the heart and major vessels. The right lung is larger than the left lung, and the left lung is smaller. The right lung is divided into three lobes, and the left lung is divided into two lobes. The right lung is also divided into three segments, and the left lung is divided into two segments. The right lung is also divided into three segments, and the left lung is divided into two segments.

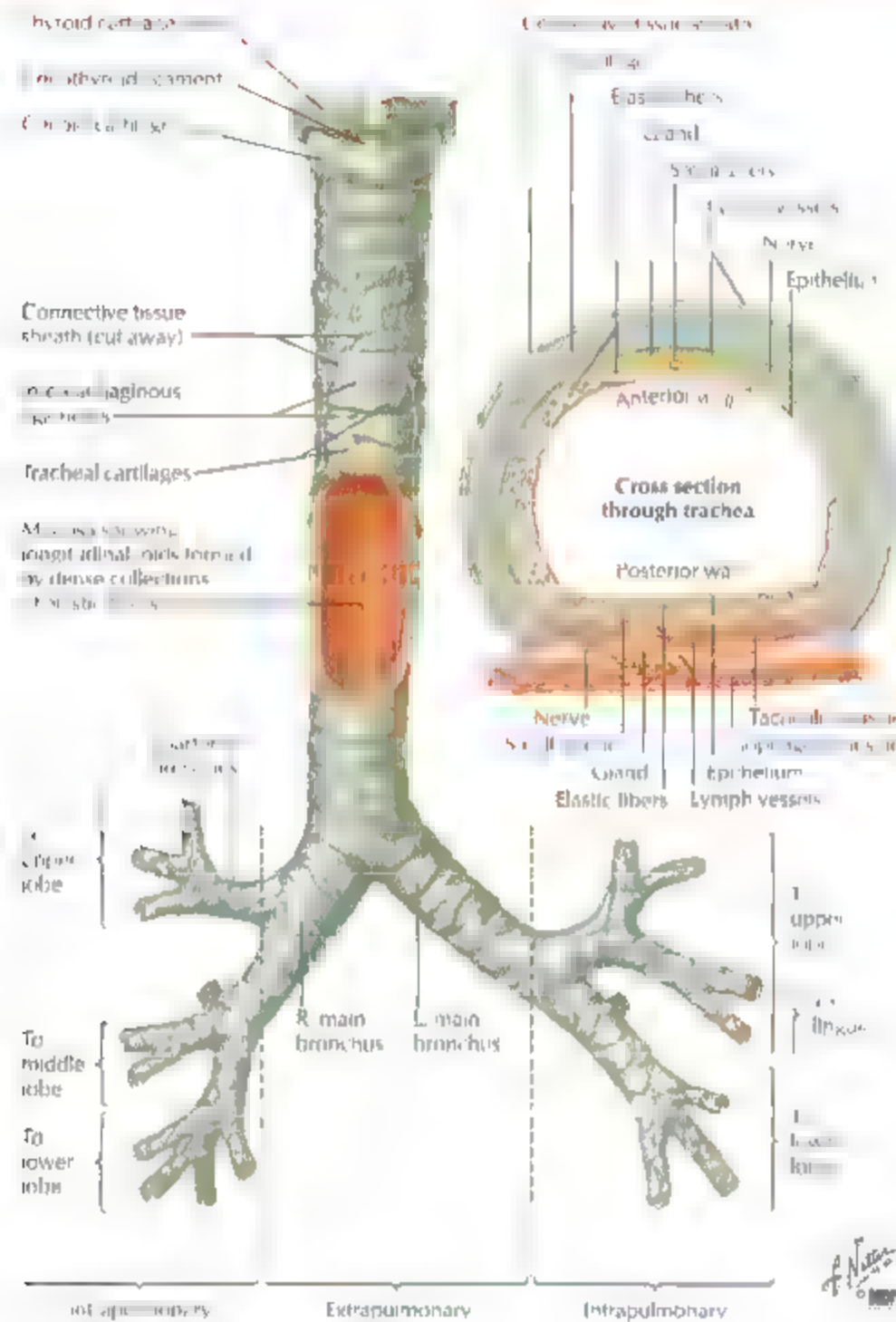


FIGURE 5.2 STRUCTURE OF THE TRACHEA AND MAJOR BRONCHI

The trachea and bronchi are part of the respiratory system. The trachea is the windpipe, and the bronchi are the branching tubes that lead to the lungs. The trachea is located in the neck, and the bronchi are located in the chest. The trachea is made of cartilage and muscle, and the bronchi are made of smooth muscle. The trachea and bronchi are lined with a mucous membrane that helps to trap dust and germs. The trachea and bronchi are also responsible for moving air in and out of the lungs.

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palace was a large building representing a palace or apartment
some of the old foundations are lined with alabaster
columns and walls representing the "apartment complex"

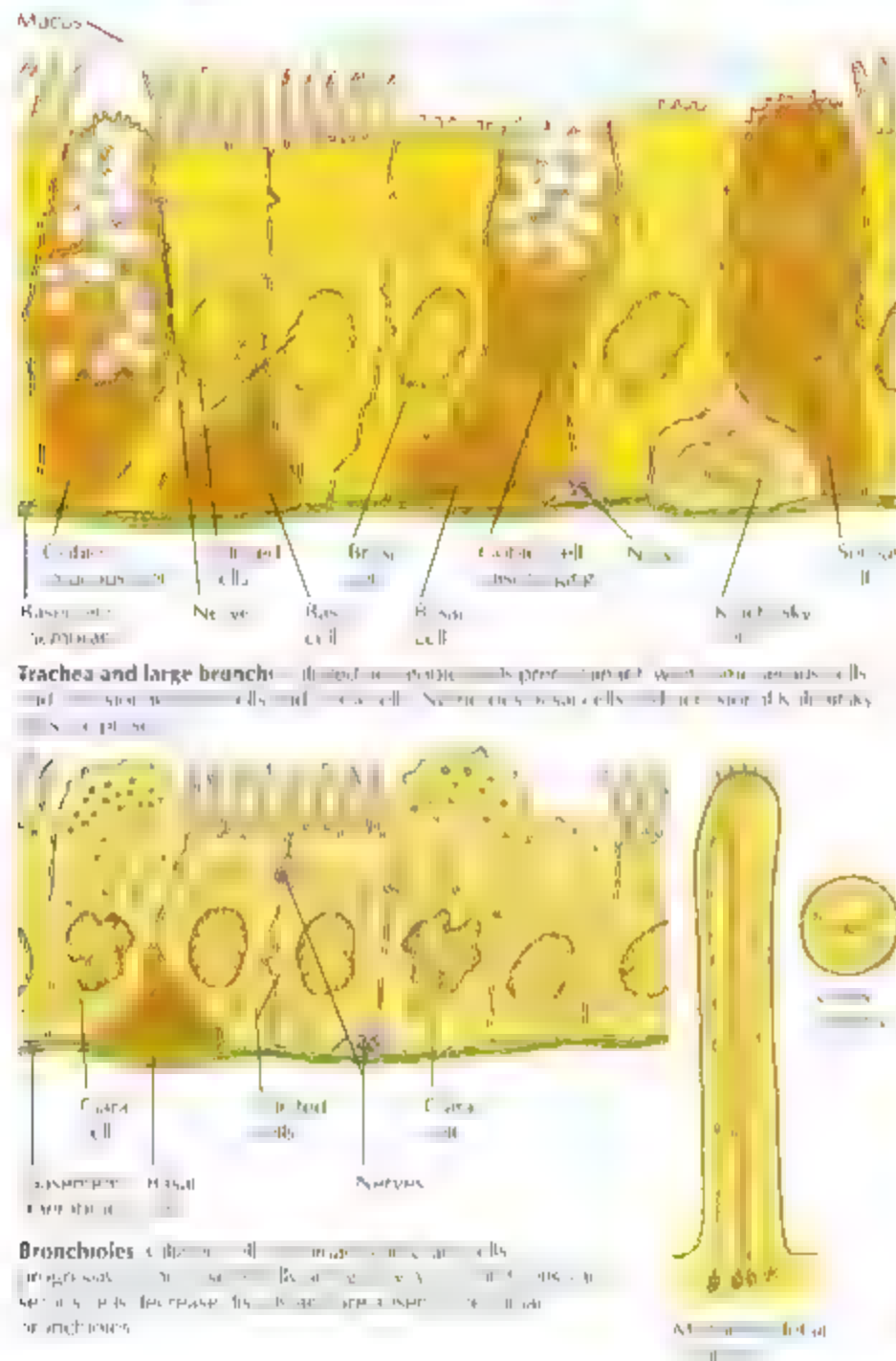


FIGURE 5.4 ULTRASTRUCTURE OF TRACHEAL, BRONCHIAL, AND BRONCHIOLAR EPITHELIUM

The respiratory tract is lined by a mucous membrane. In the trachea and large bronchi, the epithelium is stratified and contains many goblet cells that secrete mucus. The bronchioles have a simpler, cuboidal epithelium with fewer goblet cells. The alveoli are lined by a very thin, simple cuboidal epithelium. The basement membrane is prominent in the trachea and bronchi but is absent in the alveoli. The smooth muscle layer is also more prominent in the larger airways.

The cells of the respiratory tract are specialized for their function. Goblet cells are responsible for the production and secretion of mucus. Ciliated cells move mucus and trapped particles out of the airways. The simple cuboidal cells of the alveoli are specialized for gas exchange. The thick, stratified epithelium of the trachea and bronchi provides a barrier to infection and injury.

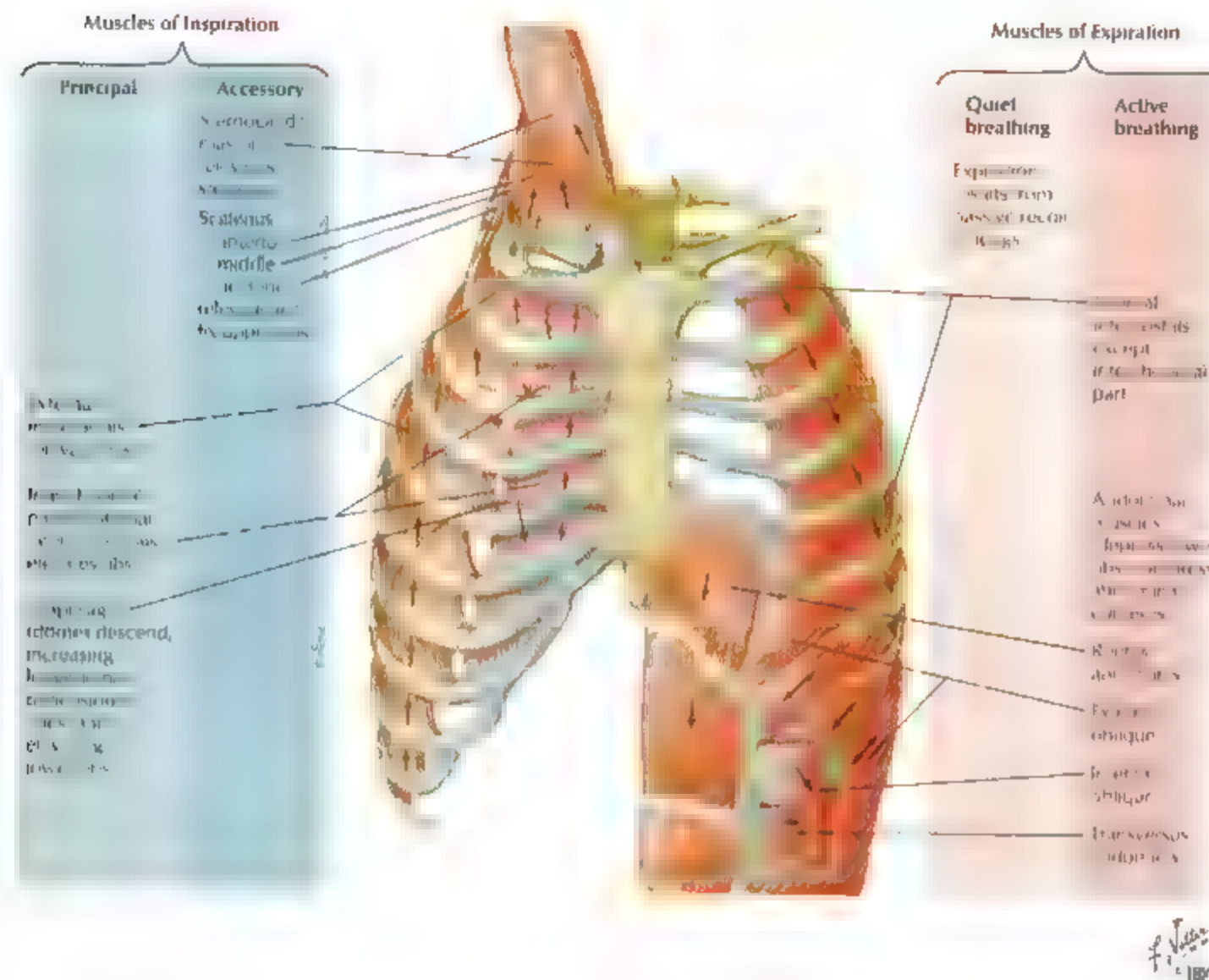


FIGURE 5.5 RESPIRATORY MUSCLES

For quiet respiration contraction of the diaphragm alone is sufficient to draw air into the lungs. Accessory muscles are recruited during more rapid breathing and selected muscles of the neck and abdomen also contract.

During inspiration and active expiration the diaphragm contracts, especially during active expiration (e.g., during exercise).

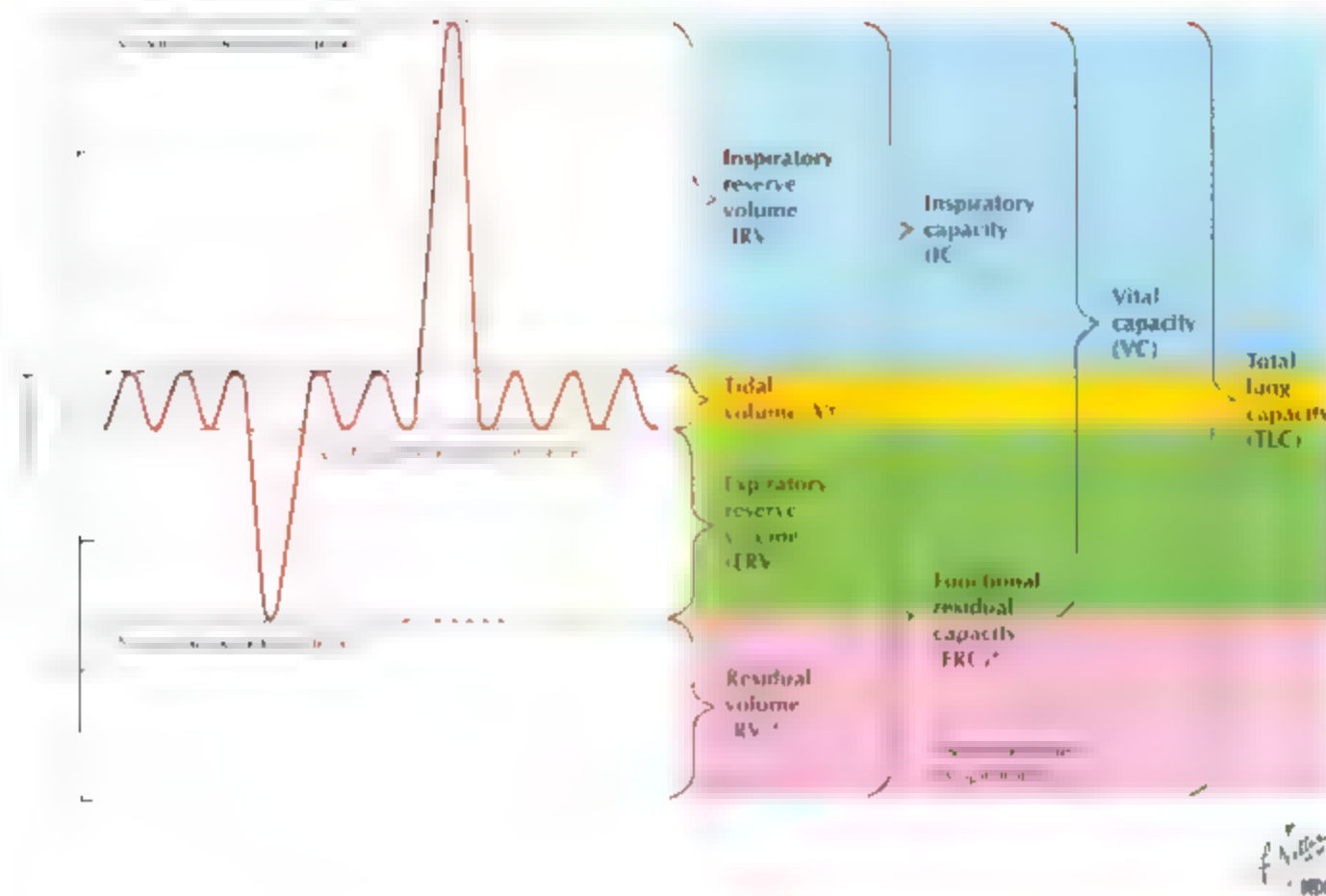
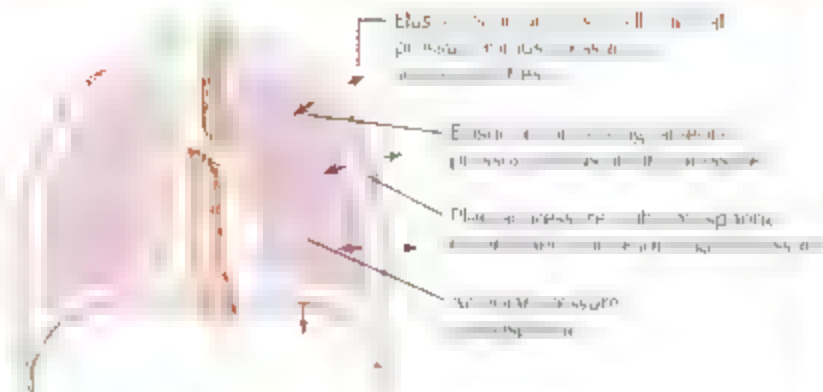


FIGURE 5.6 SPIROMETRY

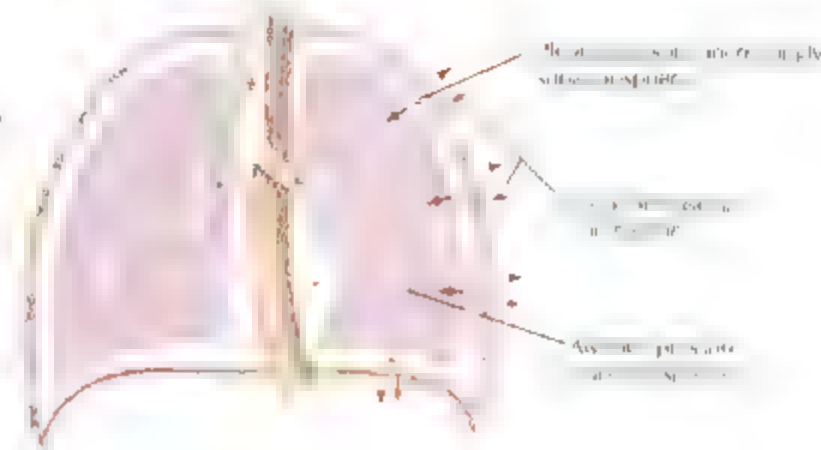
A. At rest

Respiratory muscles are at rest.
 Chest wall and lungs are in equilibrium.
 Pressure inside the lungs is equal to atmospheric pressure.
 No air flow.



B. During inspiration

Respiratory muscles contract.
 Volume of the thoracic cavity increases.
 Pressure inside the lungs decreases.
 Air flows into the lungs.



C. During expiration

Respiratory muscles relax.
 Volume of the thoracic cavity decreases.
 Pressure inside the lungs increases.
 Air flows out of the lungs.

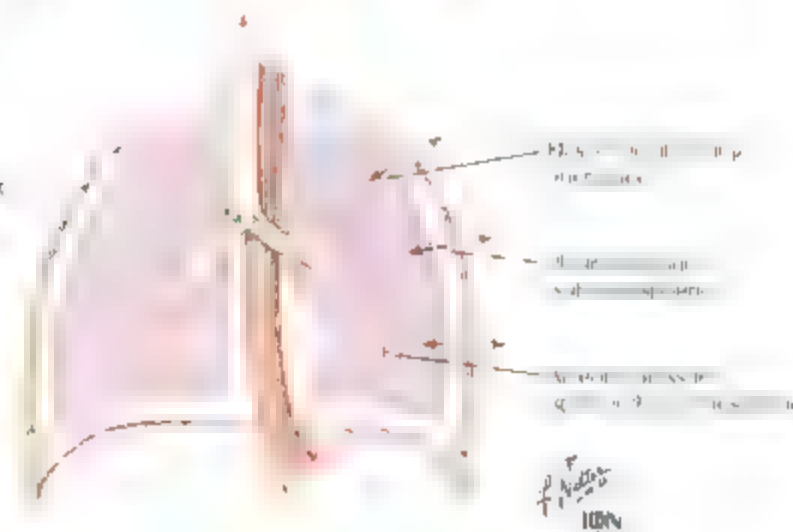


FIGURE 5.7 FORCES DURING QUIET BREATHING

The diagram illustrates the dynamic interactions between the lungs, chest wall, and pleural cavity during quiet breathing. The interplay of these structures and the resulting pressure gradients (intrapleural, atmospheric, and lung pressures) governs the flow of air into and out of the lungs.

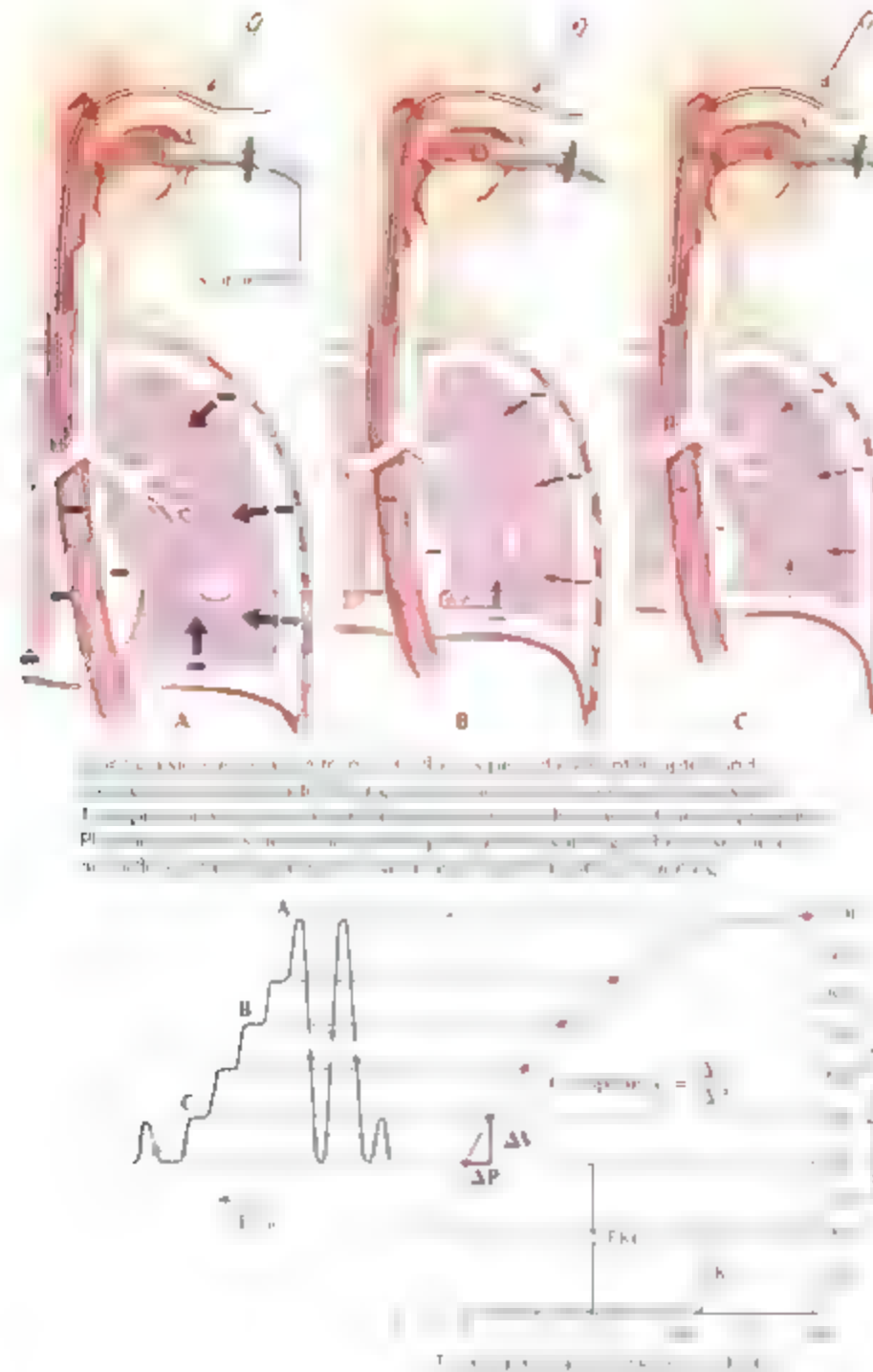


FIGURE 5.8 MEASUREMENT OF ELASTIC PROPERTIES OF LUNG.

The figure shows three diagrams (A, B, C) illustrating the measurement of the elastic properties of the lung. Diagram A shows the lungs and chest wall with arrows indicating forces and pressures. Diagram B shows the lungs and chest wall with arrows indicating forces and pressures. Diagram C shows the lungs and chest wall with arrows indicating forces and pressures.

The figure also includes two graphs. The left graph shows pressure (P) vs. volume (V) with points A, B, and C marked. The right graph shows pressure (P) vs. volume (V) with a linear relationship between ΔP and ΔV , and a slope labeled FKH .

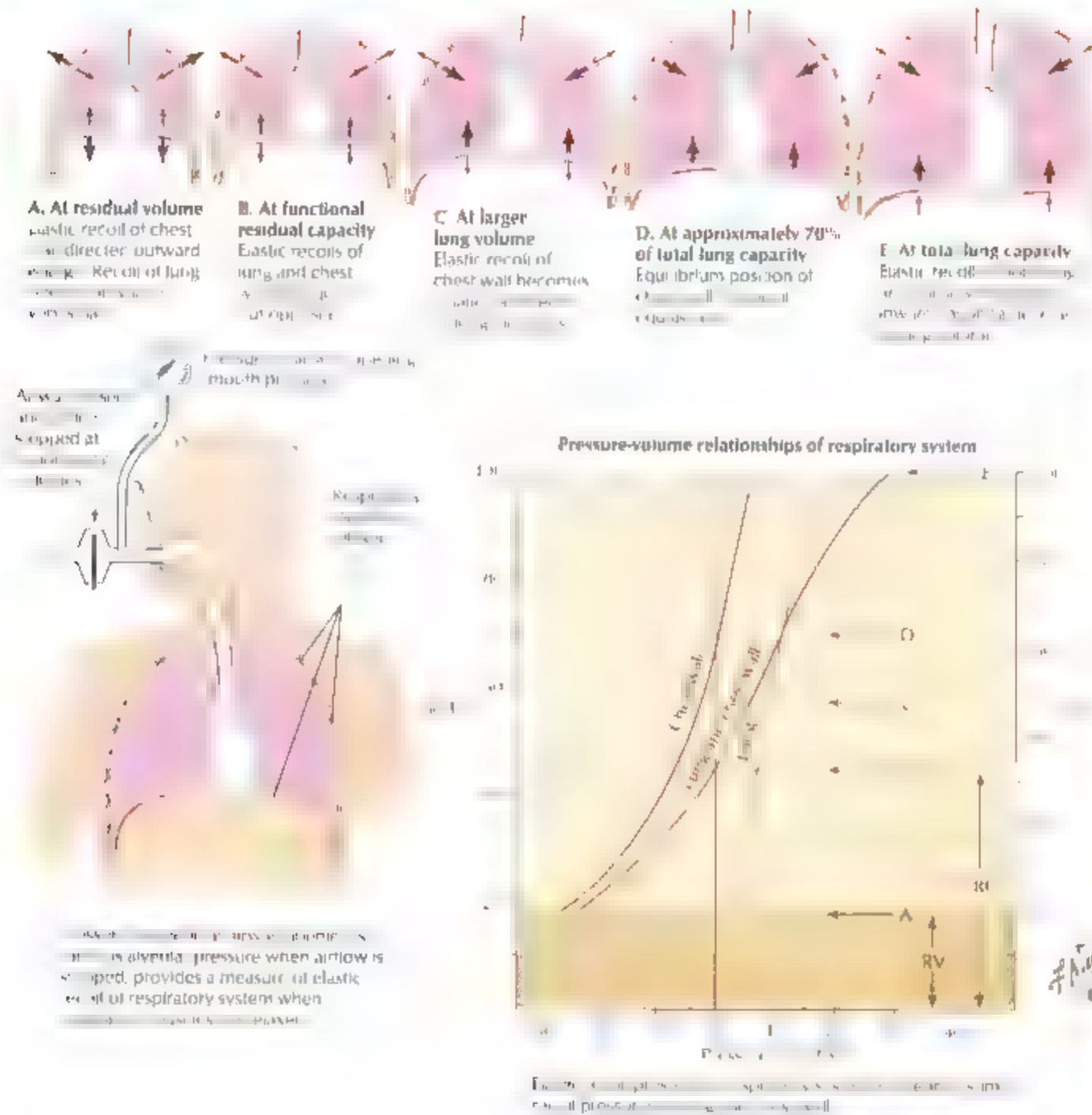


FIGURE 5.9 ELASTIC PROPERTIES OF RESPIRATORY SYSTEM: LUNG AND CHEST WALL

The elastic recoil (or compliance) properties of the lungs and chest wall alone and combined are shown diagrammatically and graphically.

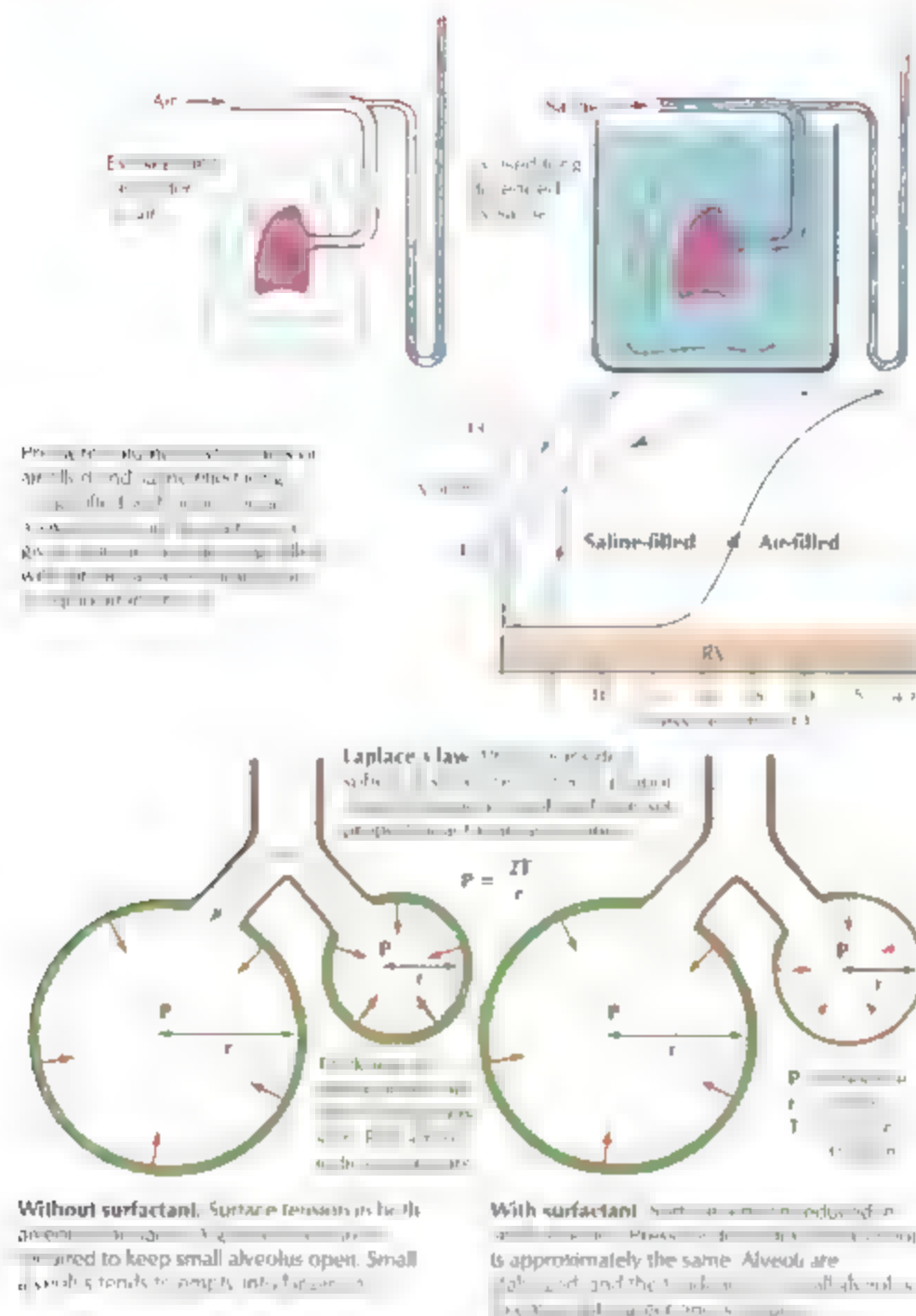
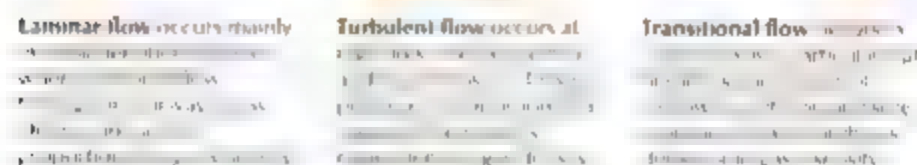
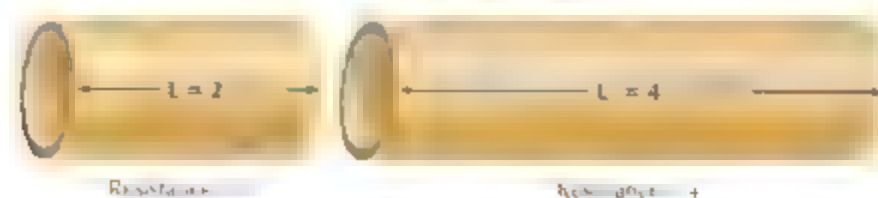


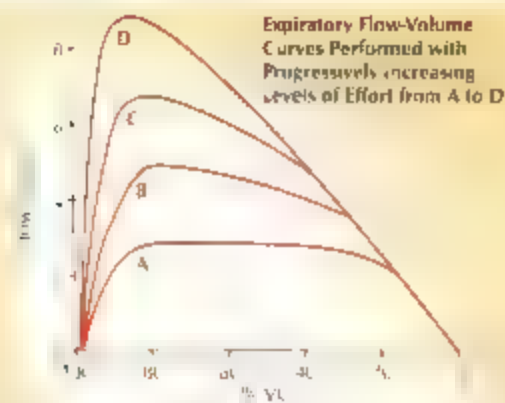
FIGURE 5.10 SURFACE FORCES IN THE LUNG

is not present with a thin film of surfactant. Laplace's law states that the pressure required to keep a small alveolus open is much greater than that required to keep a large alveolus open. This means that, without surfactant, small alveoli would collapse into larger ones.

With surfactant, the effect of surface tension is greatly reduced. This means that small alveoli can remain open and the pressure required to keep them open is much lower.

[illegible]

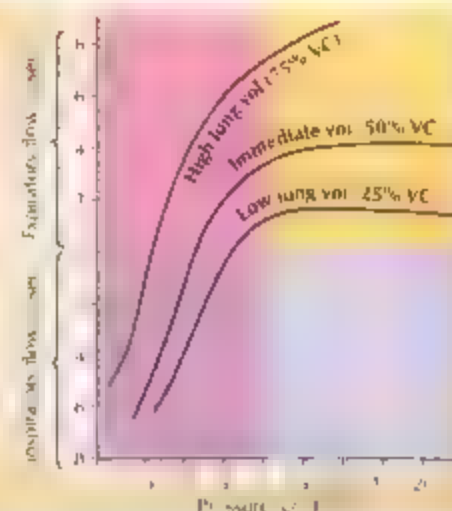
1. Definition \mathcal{H} heißt Skalarprodukt auf V , falls es eine Abbildung $\langle \cdot, \cdot \rangle : V \times V \rightarrow \mathbb{R}$ gibt, die die folgenden Eigenschaften erfüllt:



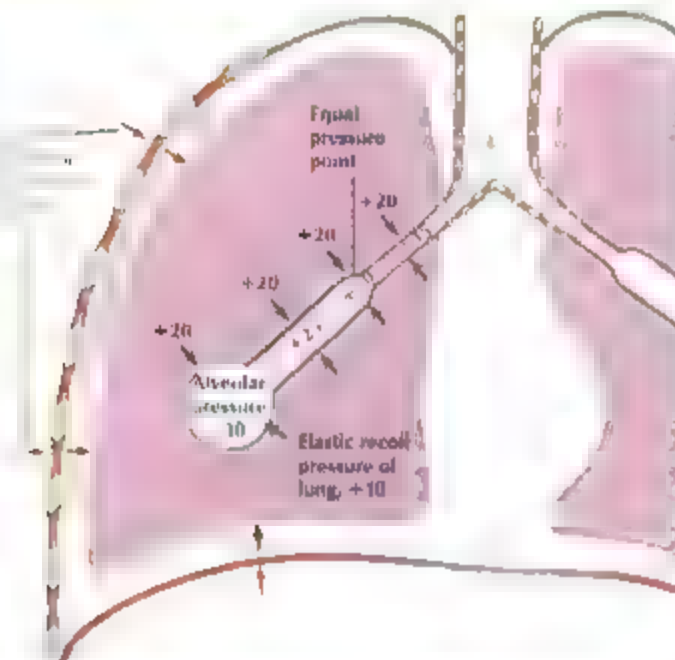
- Lung volume rate of airflow during expiration increases progressively as effort is applied. At the immediate end of expiration, the flow rate is small but increases rapidly as the effort is increased.
- As the effort increases, the flow rate increases further despite the fact that the pressure in the alveoli is already high.

Isovolumic Pressure-Flow Curves

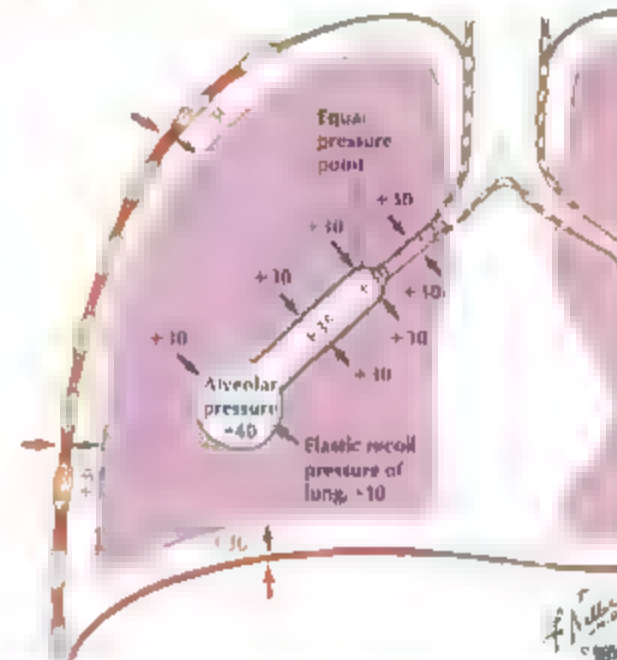
At lung volumes 15%, 50%, and 75% VC, the pressure-flow curves are shown. At low lung volumes, the pressure in the alveoli is low, and the flow rate is high. As the lung volume increases, the pressure in the alveoli increases, and the flow rate decreases.



Determinants of Maximal Expiratory Flow



At maximal expiration, the pressure in the alveoli is +10 cm H₂O, and the pressure in the airways is +20 cm H₂O. The pressure in the atmosphere is 0 cm H₂O. The flow is out of the lung.



At a higher lung volume, the pressure in the alveoli is +40 cm H₂O, and the pressure in the airways is +30 cm H₂O. The pressure in the atmosphere is 0 cm H₂O. The flow is out of the lung.

FIGURE 5.12 FLOW-VOLUME RELATIONSHIPS

Flow varies as a function of pressure and lung volume. The highest rates of airflow are seen at high lung volumes.

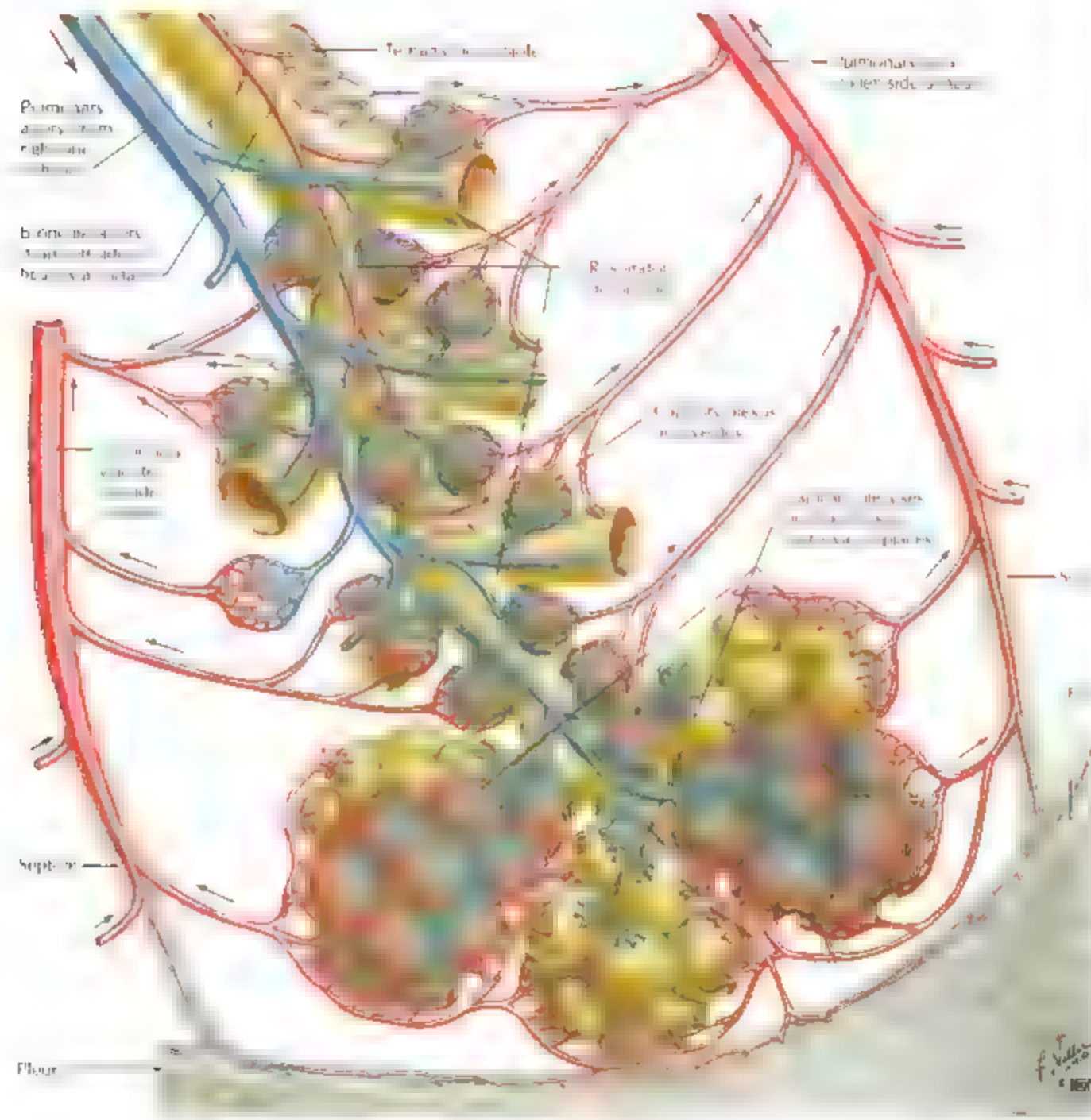


FIGURE 5.13 INTRAPULMONARY BLOOD CIRCULATION

Blood from the right ventricle of the heart perfuses the lung via the pulmonary artery. The pressure in the pulmonary artery is about 120 mm Hg under low pressure. The pressure in the pulmonary artery is about 120 mm Hg under low pressure. The pressure in the pulmonary artery is about 120 mm Hg under low pressure.

Blood from the left atrium of the heart returns to the right side of the heart via the pulmonary veins. The pressure in the pulmonary veins is about 120 mm Hg under low pressure. The pressure in the pulmonary veins is about 120 mm Hg under low pressure.

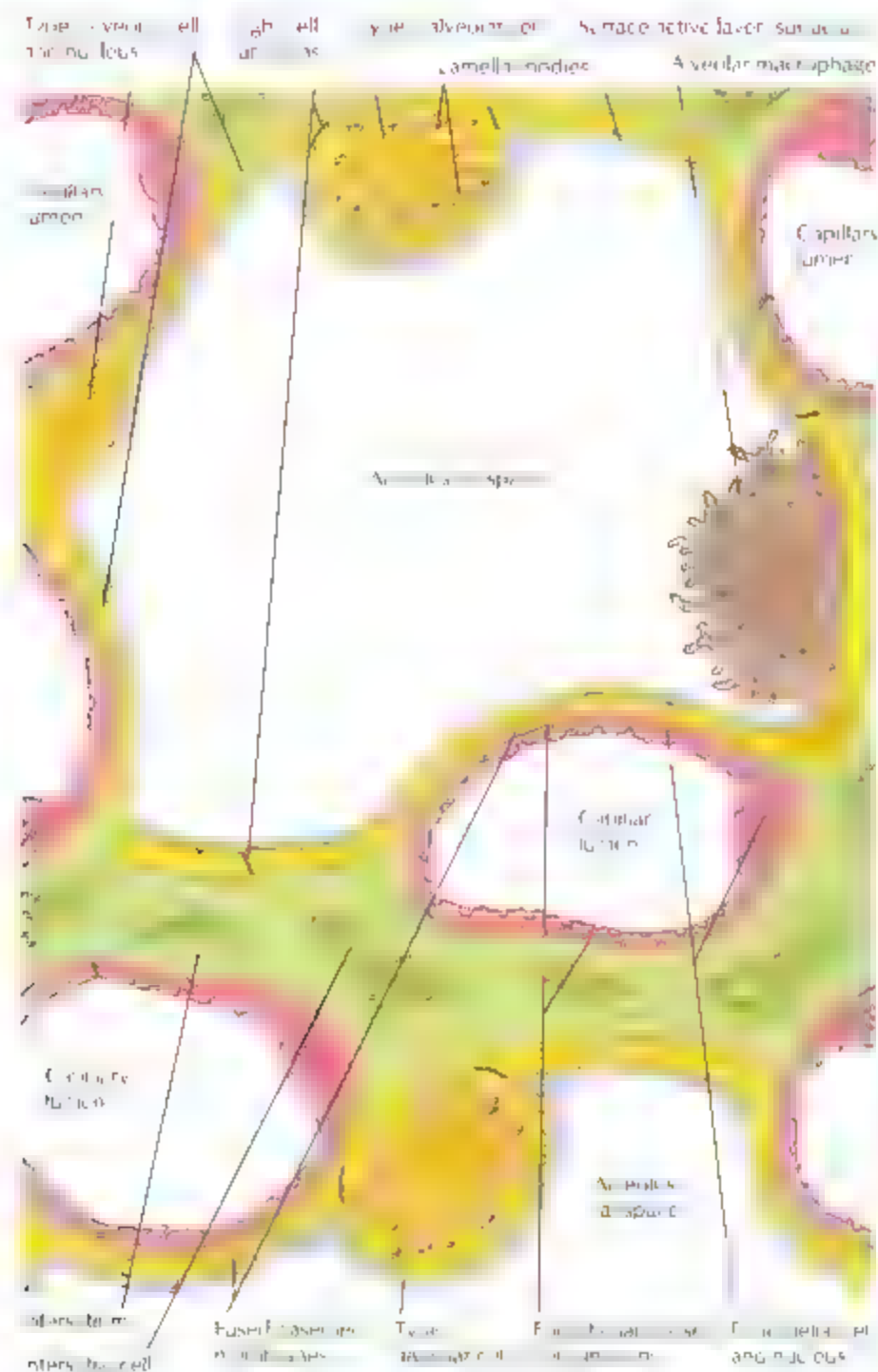


FIGURE 5.14 ULTRASTRUCTURE OF PULMONARY ALVEOLI AND CAPILLARIES

Alveolar macrophages are cells that reside in the alveolar space and are responsible for the removal of debris and pathogens. They are characterized by their large size and the presence of numerous lysosomes and phagocytic granules. In the electron micrograph, they are seen as large, rounded cells with a prominent nucleus and a foamy or vacuolated cytoplasm. They are often found near the alveolar surface, where they can ingest inhaled particles and microorganisms.

Capillaries are small blood vessels that are responsible for the exchange of gases and nutrients between the alveoli and the rest of the body. They are characterized by their thin walls and the presence of a single layer of endothelial cells. In the electron micrograph, they are seen as small, circular structures with a clear lumen and a thin, dark border representing the endothelial lining.

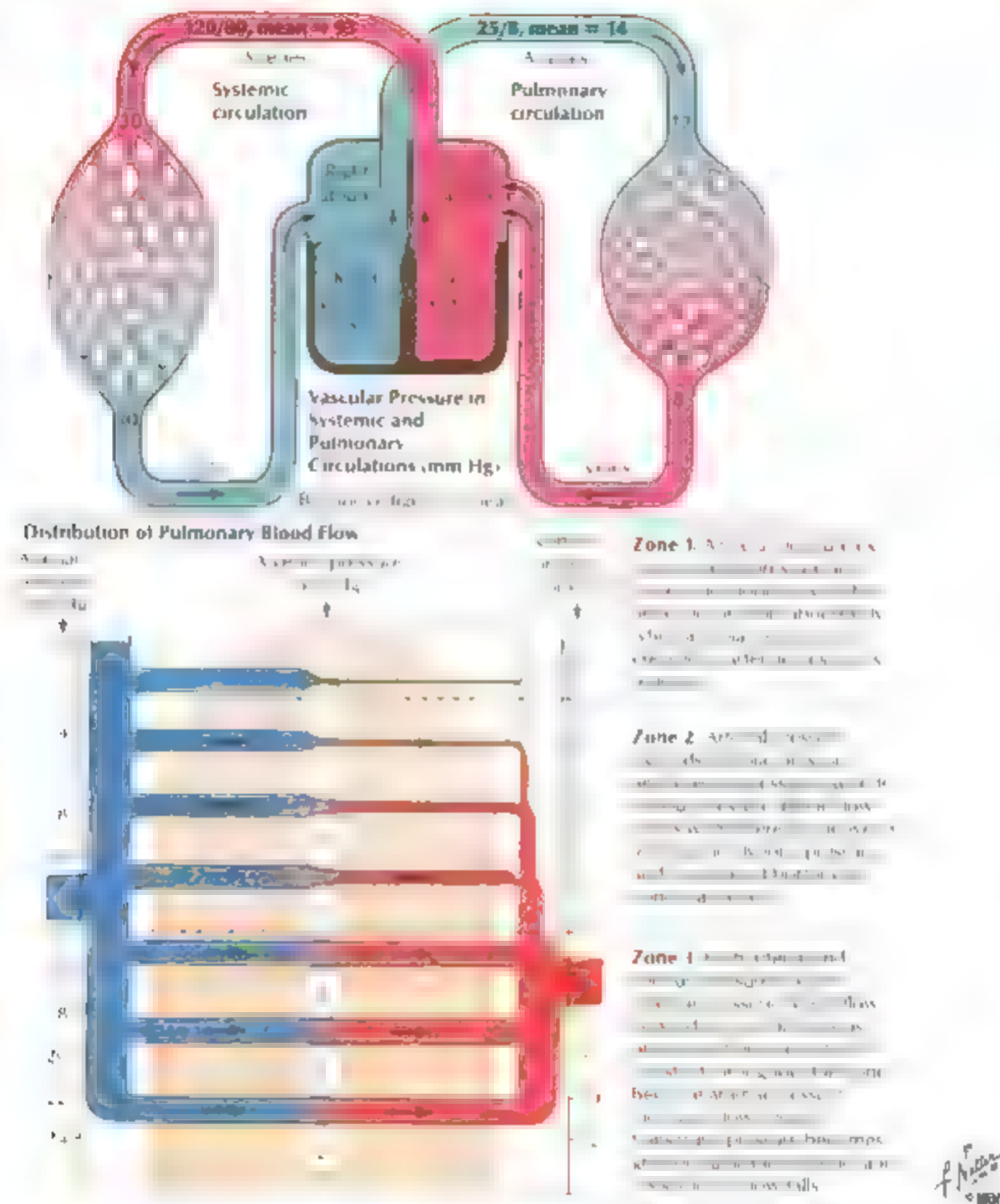
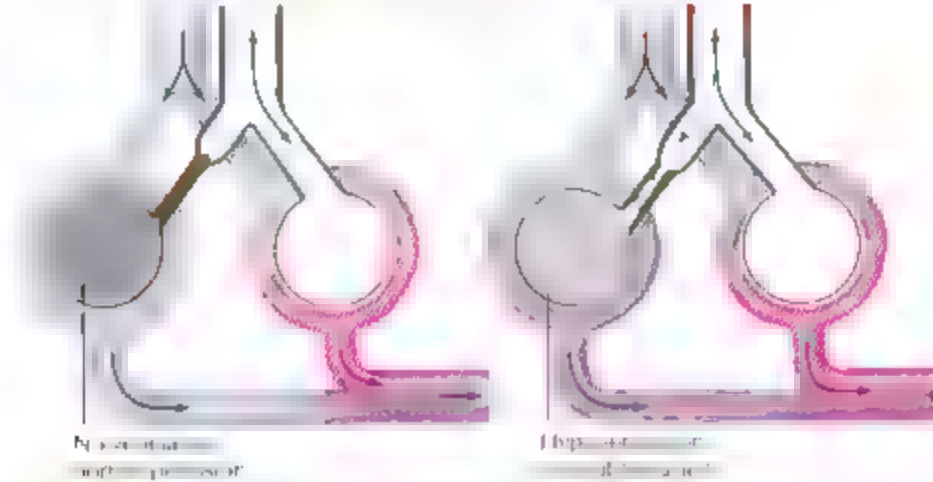


FIGURE 5.15 PULMONARY CIRCULATION

the pulmonary blood flow is normally distributed throughout the lung. As the alveolar pressure increases, the blood flow is increasingly diverted to the lower zones.

normal pulmonary blood flow is about 5 L/min. The pulmonary circulation is a low-pressure system, and the pulmonary pressure is normally about 12 mm Hg.

A. Conditions with low ventilation/perfusion ratio



B. Conditions with high ventilation/perfusion ratio

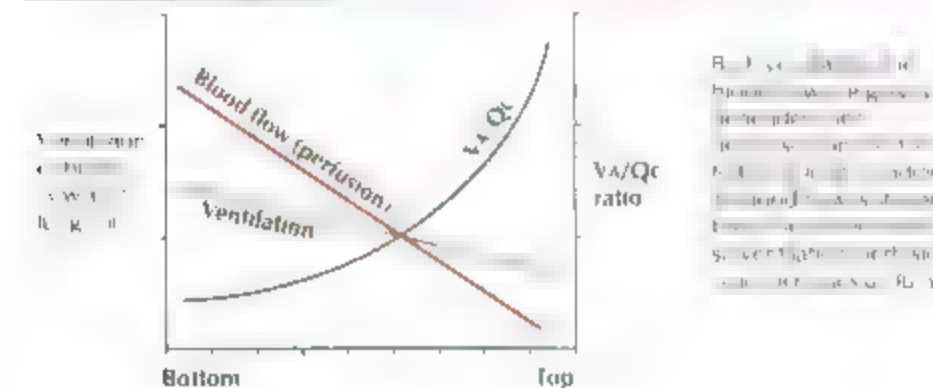
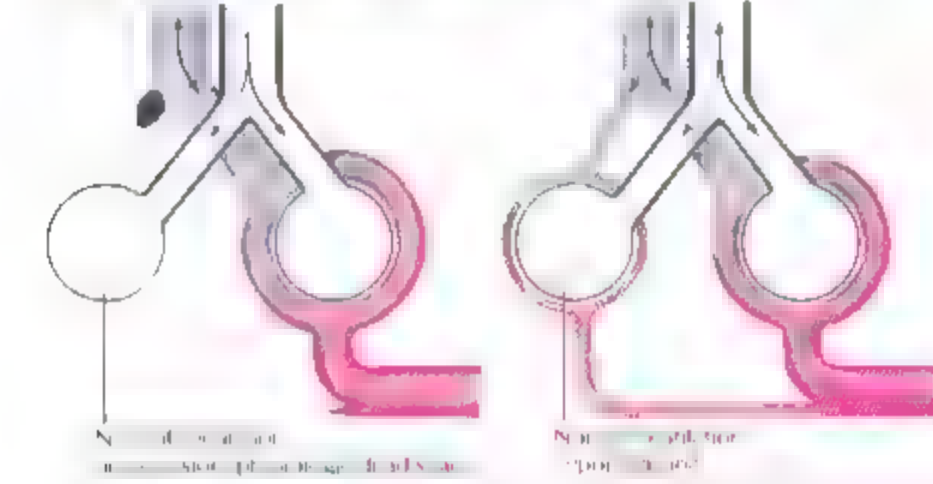


FIGURE 5-16 VENTILATION/PERFUSION (V_A/Q_c) RELATIONSHIPS

ffects not only capillary perfusion (see Figure 5-15) but also ventilation as well. In an extreme, perfusion falls after ventilation. Perfusion (V_A/Q_c) is greater at the top of the lung than at the bottom.

low blood flow, whereas the opposite is true at the base. In a normal lung, on average, V_A/Q_c is approximately

Effects of chemical and humoral substances

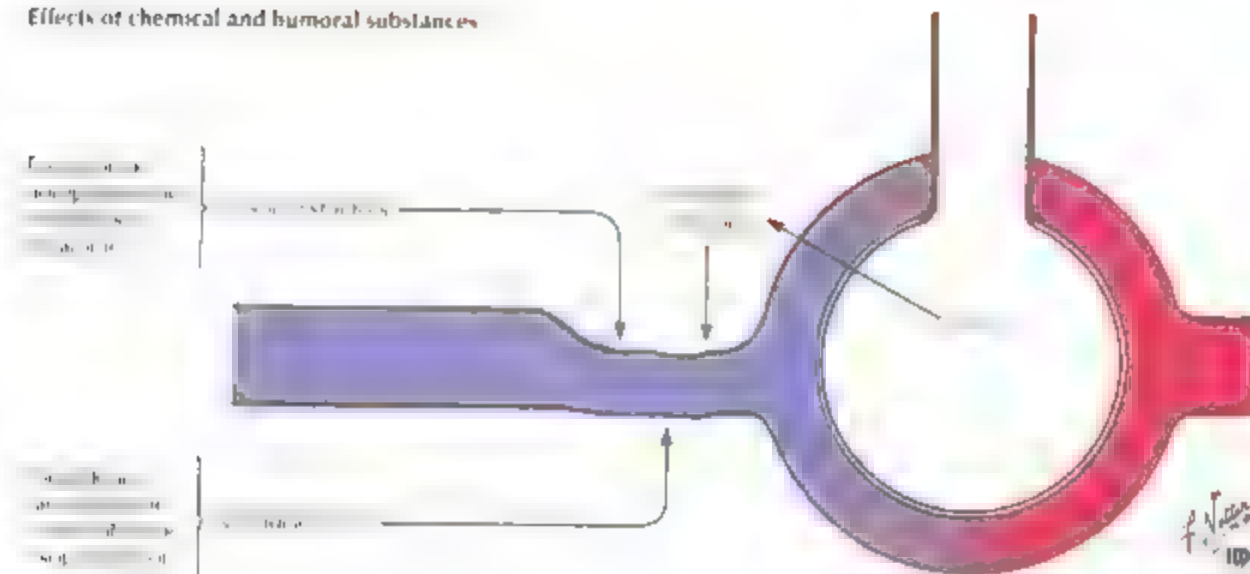


FIGURE 5.17 PULMONARY VASCULAR RESISTANCE

Pulmonary vascular resistance is the resistance to blood flow in the pulmonary circulation. It is determined by the relationship between pulmonary blood flow and the pressure gradient across the pulmonary circulation. The pressure gradient is the difference between the pulmonary artery pressure and the pulmonary vein pressure. The pulmonary artery pressure is the pressure in the main pulmonary artery, and the pulmonary vein pressure is the pressure in the pulmonary veins. The pulmonary vascular resistance is calculated as the pressure gradient divided by the pulmonary blood flow.

The pulmonary vascular resistance is a measure of the resistance to blood flow in the pulmonary circulation. It is determined by the relationship between pulmonary blood flow and the pressure gradient across the pulmonary circulation. The pressure gradient is the difference between the pulmonary artery pressure and the pulmonary vein pressure. The pulmonary artery pressure is the pressure in the main pulmonary artery, and the pulmonary vein pressure is the pressure in the pulmonary veins. The pulmonary vascular resistance is calculated as the pressure gradient divided by the pulmonary blood flow.

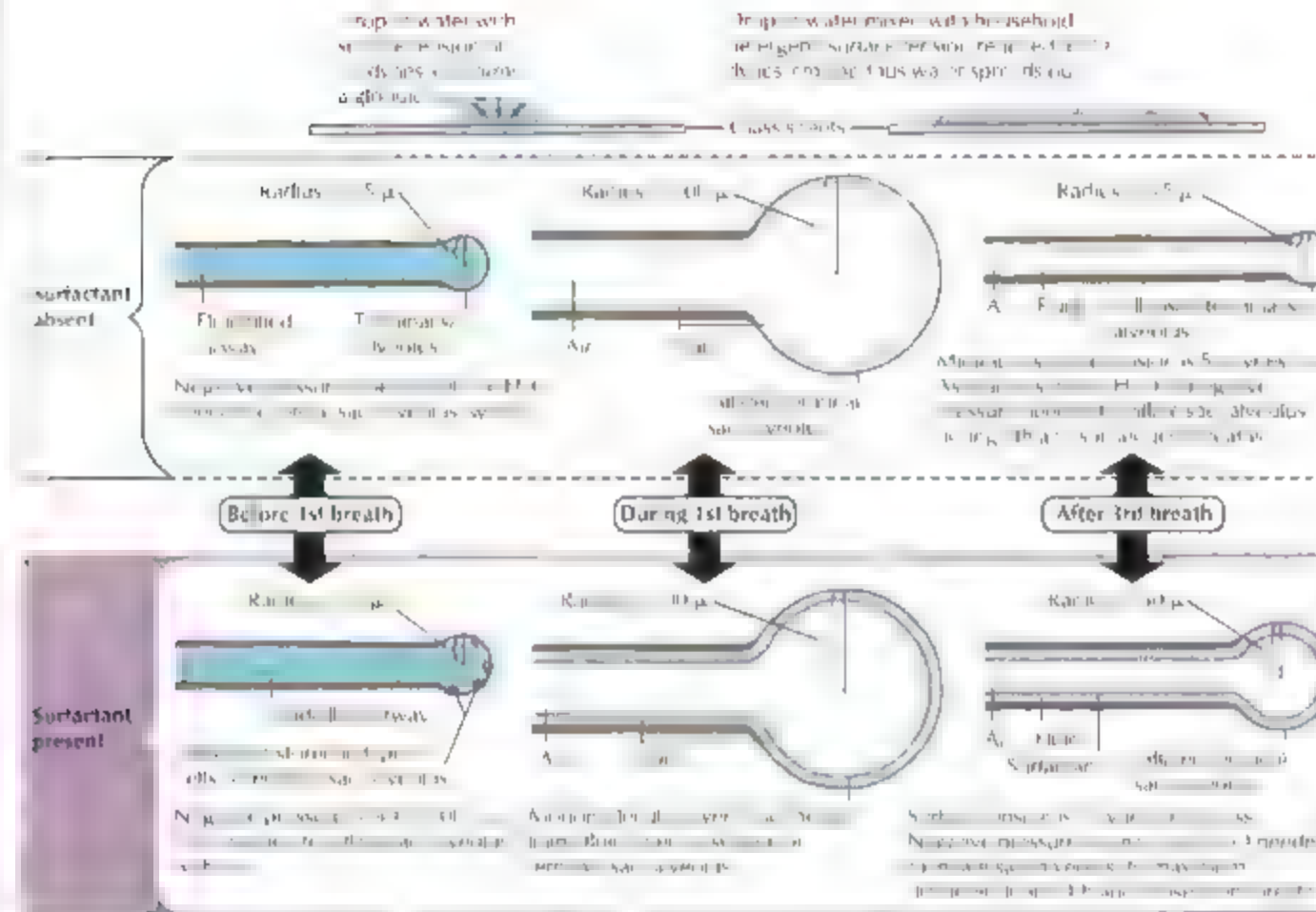
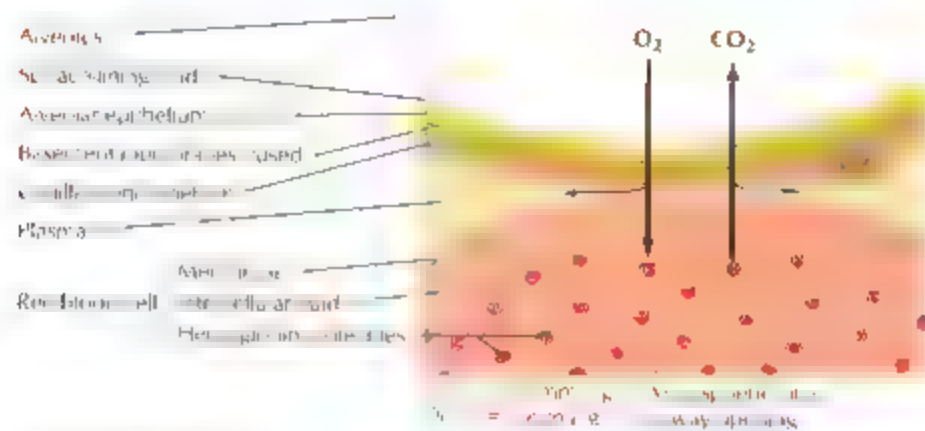


FIGURE 5.18 SURFACTANT EFFECTS

Surfactant is a phospholipid that reduces surface tension. It is secreted by type II alveolar cells and is essential for normal lung function. Surfactant acts to reduce the surface tension of the fluid lining the alveoli (see Figure 5.18). Thus, lower surface tension reduces the work of breathing.

Surfactant also prevents the collapse of alveoli. Without surfactant, the high surface tension would cause the alveoli to collapse at the end of expiration, making breathing difficult.

Pathways of O₂ and CO₂ Diffuse



Transfer of O₂ and CO₂ Between Alveolar Air and Capillary Blood

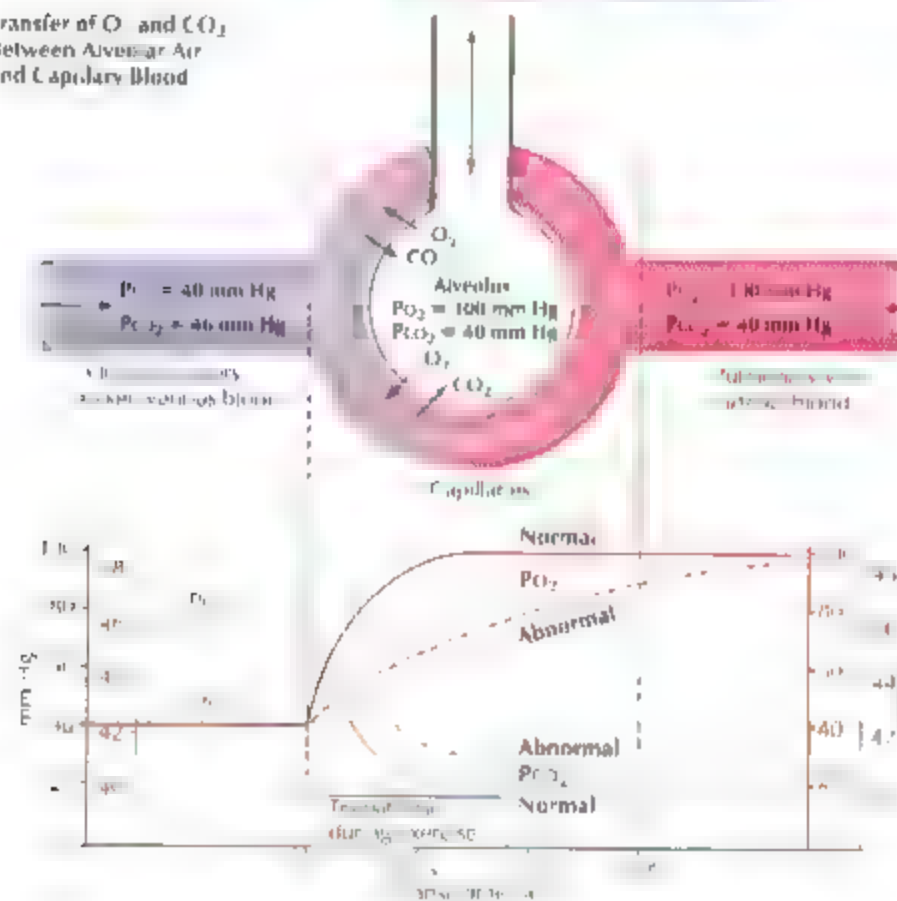


FIGURE 5.19 O₂ AND CO₂ EXCHANGE

As blood flows through the alveoli, it picks up O₂ and releases CO₂. The alveoli are the site of gas exchange between the atmosphere and the blood. A thin layer of surfactant lines the alveoli, and the blood is in contact with the alveolar wall. Normally, the entire length of the capillary is used for gas exchange. In some cases, the blood does not reach the end of the capillary before equilibrium is reached. This is called a V/Q mismatch. In some cases, the blood does not reach the end of the capillary before equilibrium is reached. This is called a V/Q mismatch.

When the partial pressures of O₂ and CO₂ in the alveoli are low, as in some diseases, the rate of gas exchange is reduced. This is because the partial pressure of O₂ in the alveoli is low, and the partial pressure of CO₂ in the alveoli is high. This leads to a V/Q mismatch, where the blood does not reach the end of the capillary before equilibrium is reached. This is called a V/Q mismatch.

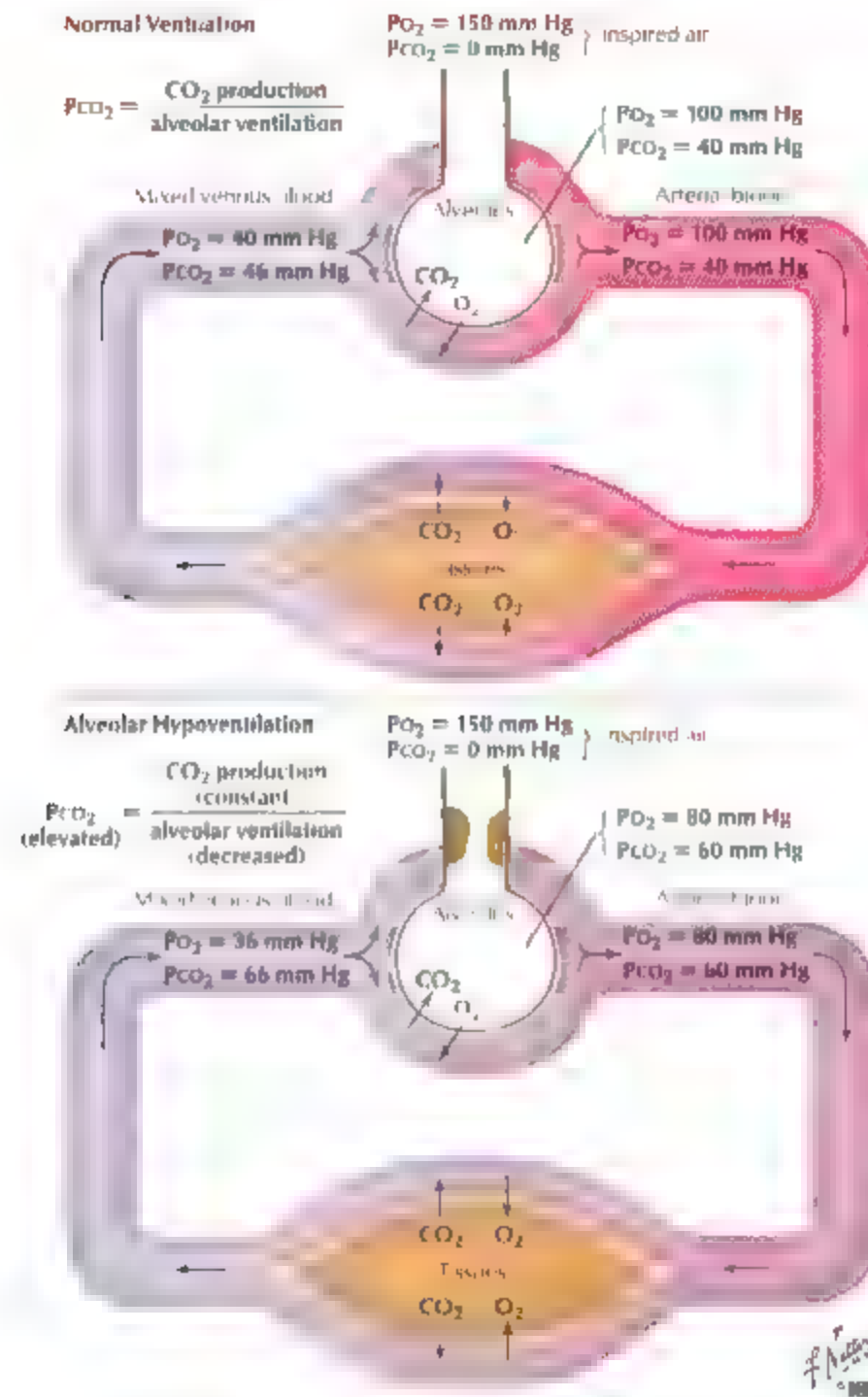


FIGURE 5.20 O₂ and CO₂ Exchange and Transport

Alveolar hypoventilation (as illustrated here) is a partial blockage of the airway, reducing alveolar P_{O_2} and increasing P_{CO_2} (hypercapnia). As a result, arterial P_{O_2} decreases (hypoxia) and arterial P_{CO_2} increases (hypercapnia).

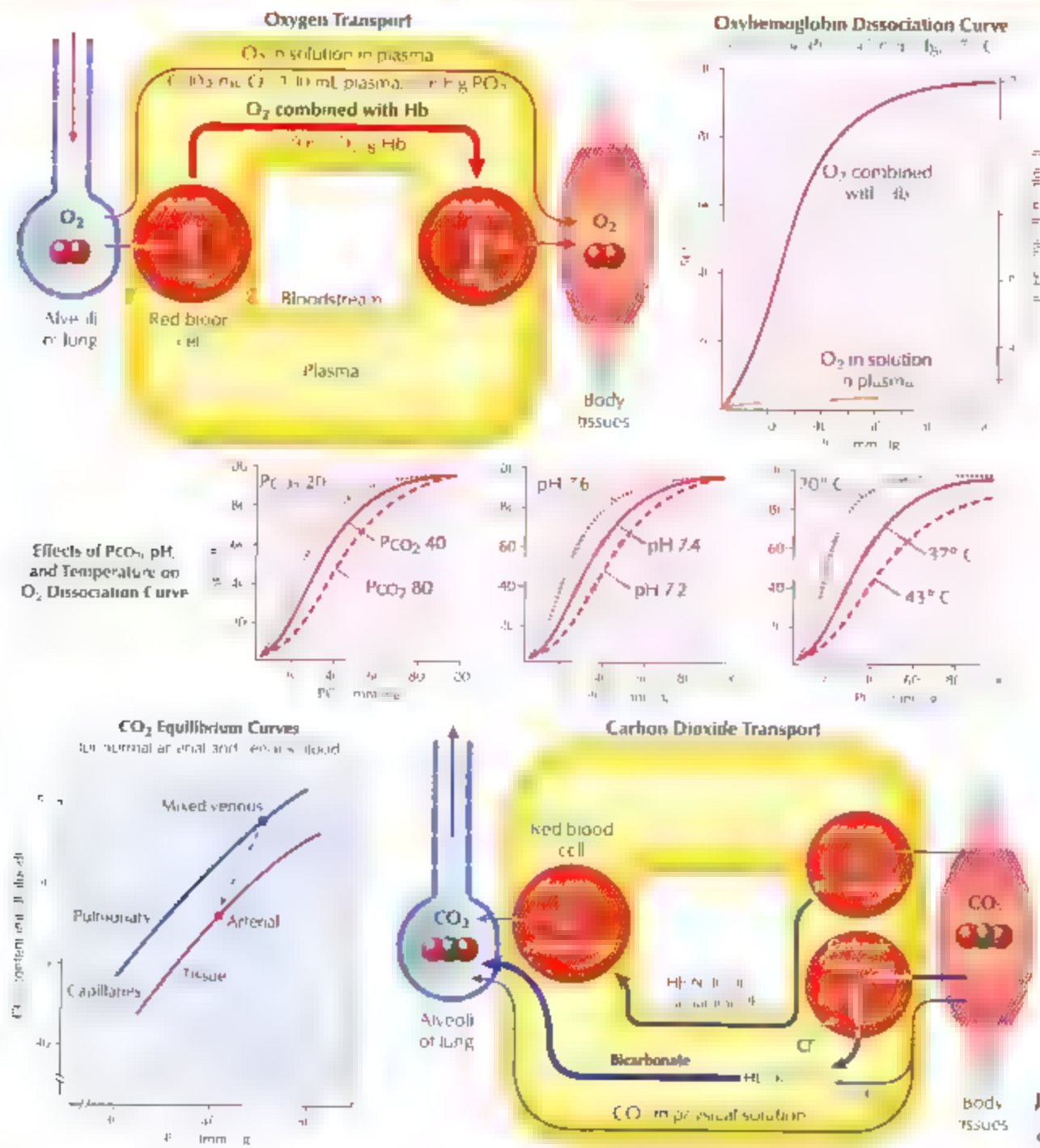


FIGURE 5.21 O₂/CO₂ EXCHANGE

During each breath, O₂ and CO₂ are exchanged across the alveolar-pulmonary capillary membrane (see Figure 5.19). Almost all of the O₂ carried to the tissues is bound to hemoglobin (Hb), only a small amount is dissolved and transported in plasma. As shown in the oxyhemoglobin dissociation curve, the binding of O₂ to Hb is dependent on the partial pressure of O₂ (PO₂). The percent saturation of Hb is about 97.5% when the PO₂ is 100 mm Hg. In the three middle panels, the effects of pH, PCO₂, and temperature on the oxyhemoglobin dissociation curve are shown. Hb binding is decreased,

and thereby offloading of O₂ to the tissues is increased by increases in PCO₂ (hypercapnia), decreased pH (acidosis), or increased body temperature (fever). CO₂ from the tissues is transported in the form of HCO₃⁻. A small amount is transported in the dissolved form and some is carried in the form of carbaminohemoglobin. The bottom panel shows the CO₂ equilibrium dissociation curve, which is much steeper than that for O₂, which is why the PO₂ difference between arterial and mixed venous blood is small (about 5 mm Hg).

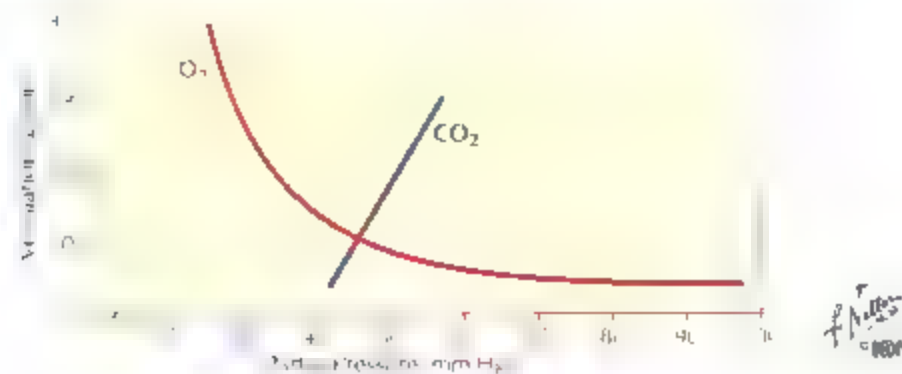
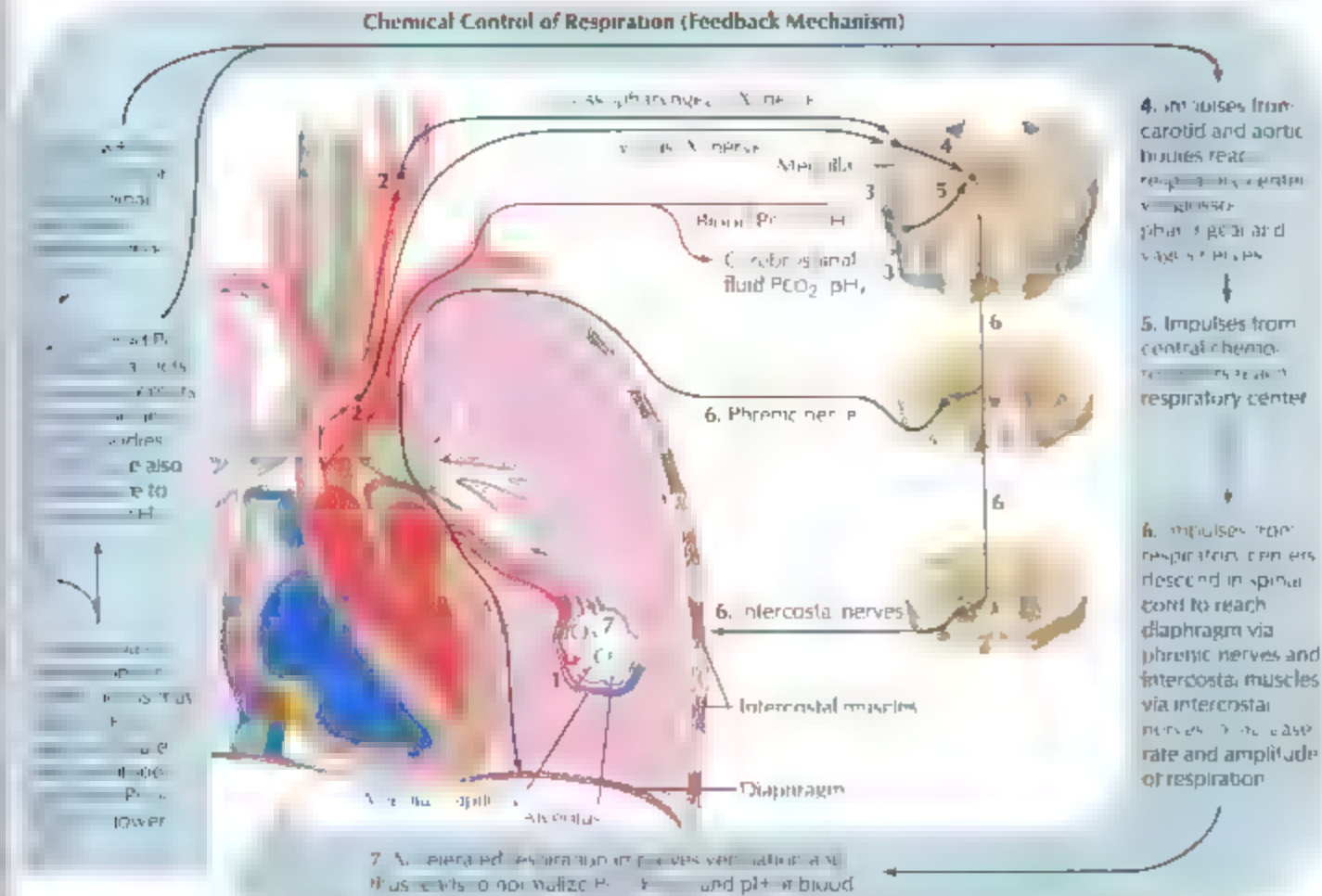
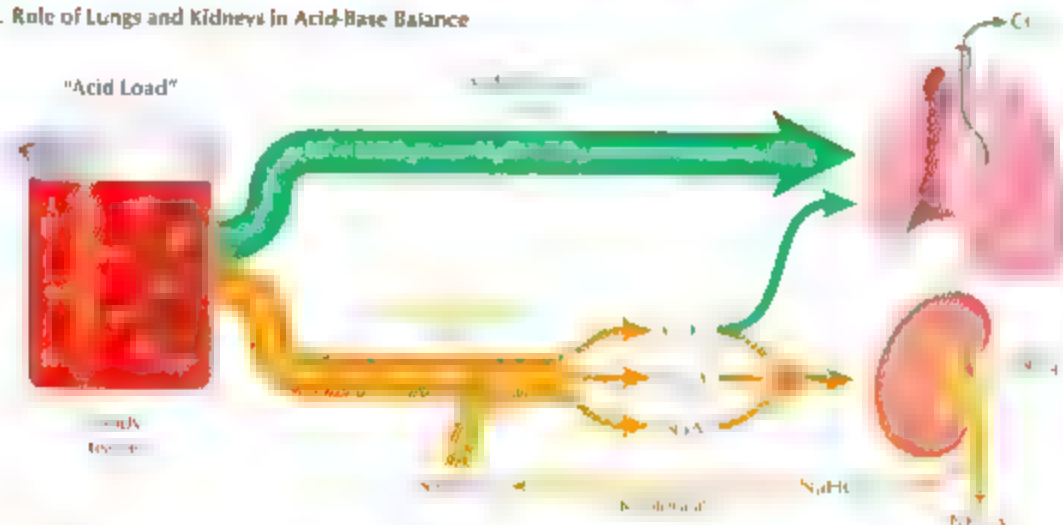


FIGURE 5.22 CONTROL OF RESPIRATION

Central chemoreceptors respond to changes in arterial P_{CO_2} and pH . Peripheral chemoreceptors respond to changes in arterial PO_2 . A decrease in arterial PO_2 stimulates peripheral chemoreceptors. A change in the pH of the cerebrospinal fluid stimulates central chemoreceptors. An increase in P_{CO_2} or a decrease in pH stimulates central chemoreceptors. A decrease in PO_2 stimulates peripheral chemoreceptors. The respiratory center in the medulla responds to these changes by increasing ventilation.

Central chemoreceptors respond to changes in arterial P_{CO_2} and pH and send signals via the phrenic and intercostal nerves to the diaphragm and intercostal muscles. This results in an increase in respiratory rate and amplitude, which leads to an increase in alveolar ventilation. A decrease in arterial pH is mediated by the peripheral chemoreceptors.

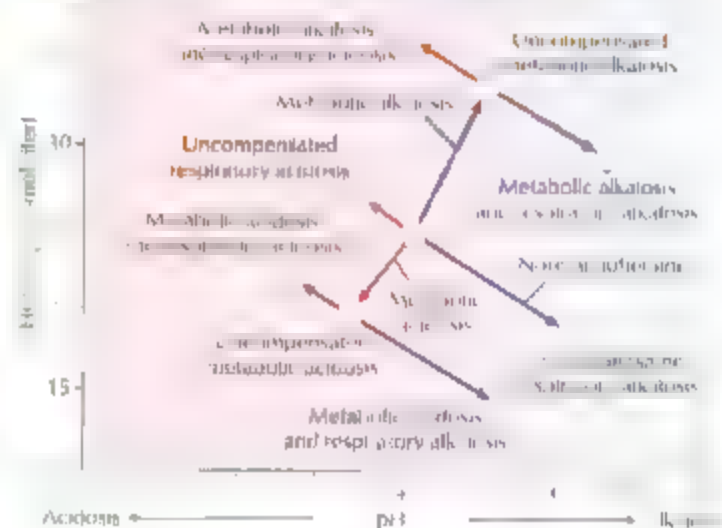
"Acid Load"



Acid-Base Pairs

Food Source	Acid Alkali	Quantity g g g
Citrus fruit		
Fruit		
Alkaline cereals		
Non-vegetable protein		
Grain		
Vegetables		
Dips and soups		
Milk products		
Total		

g = g/kg/day of nonvolatile acid production



Disorder	pH	P_{CO_2} Alteration	Defense Mechanisms
Metabolic acidosis	↓	↓ HCO_3^- ↓	Buffers, ↓ PCO_2 , ↑ NA
Metabolic alkalosis	↑	↑ HCO_3^- ↑	Buffers, ↑ PCO_2 , ↓ NA
Respiratory acidosis	↓	↑ PCO_2	Buffers & ↑ NA
Respiratory alkalosis	↑	↓ PCO_2	Buffers & ↓ NA

J. Perkins
MS, MFA
F. 1004

A. Both the lungs and kidneys participate in acid-base balance.
B. Our diet and cellular metabolism add acid and alkali to our system.
C. The body fluid system is able to buffer the extra acid or base generated by carbohydrate and fat metabolism, is efficiently eliminated by the lungs and kidneys not normally affect acid-base balance. However, failure to excrete the CO_2 can alter acid-base balance. Non-volatile acid (e.g. lactic acid) is buffered by HCO_3^- in the extracellular fluid. The kidneys excrete excess H^+ and H_2O in the urine to increase the HCO_3^- used to neutralize these acids. The kidneys do this by excreting NH_4^+ in conjunction with Na^+ and K^+ in the urine, which also results in the addition HCO_3^- to the extracellular fluid.

respond quickly and remove large quantities of volatile acid hyperventilation. The kidneys take hours or days to respond. The lungs respond and the kidneys take time to respond. The lungs respond to the acidosis resulting from alterations in the P_{aO_2} respiratory disorders. When an acid-base disturbance occurs, intracellular (primarily proteins) and extracellular (primarily HCO_3^-) buffers minimize the change in body fluid pH. Initially, the lungs can adjust the P_{aO_2} and the kidneys can adjust net acid excretion (acid for respiratory disorders and $NaHCO_3$ excretion for metabolic disorders) and the kidneys can adjust net acid excretion (acid for respiratory disorders and $NaHCO_3$ excretion for metabolic disorders).

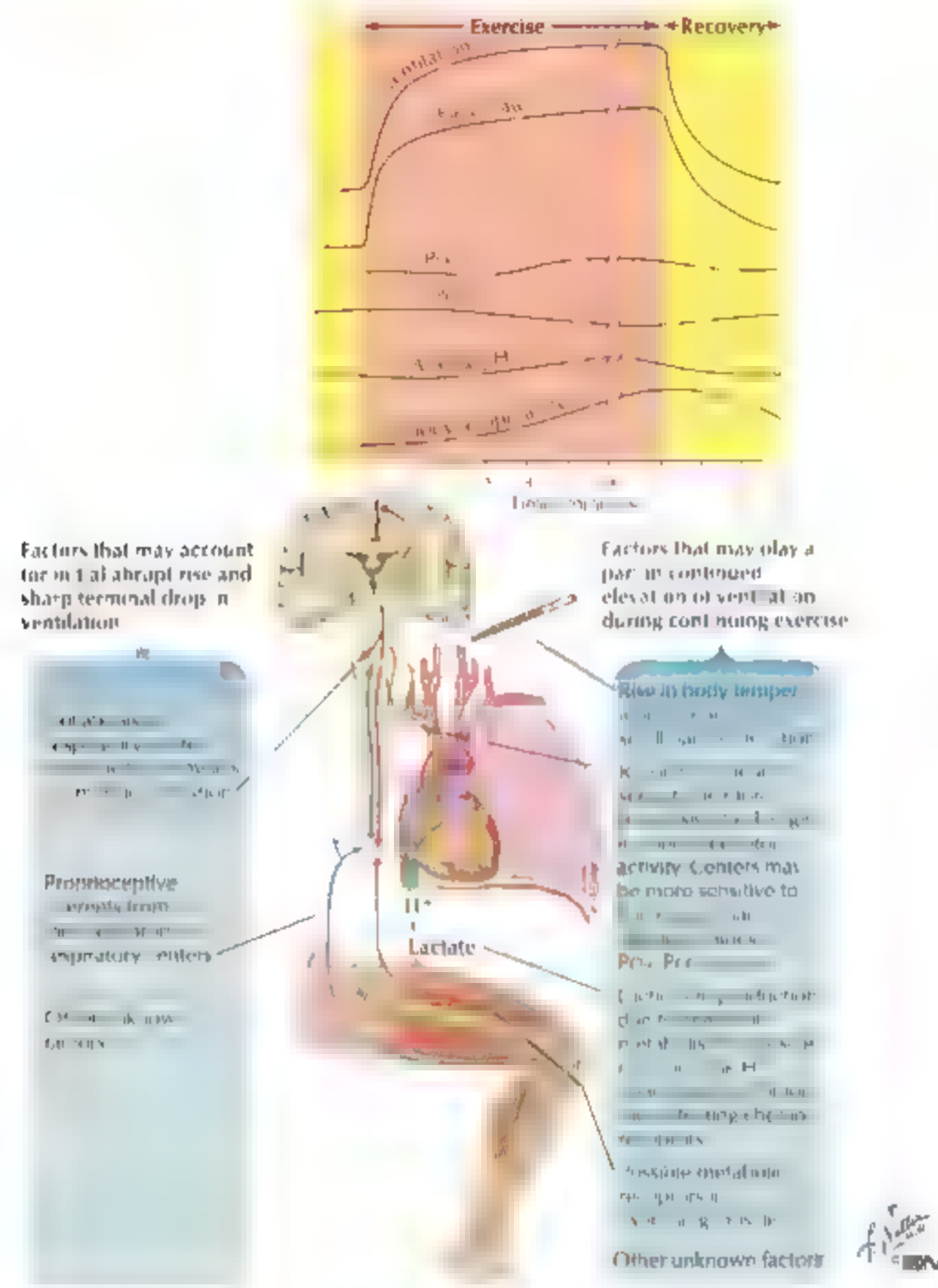


FIGURE 5.24 RESPIRATORY RESPONSE TO EXERCISE

...intensity of demand for delivery of ... the body and ...

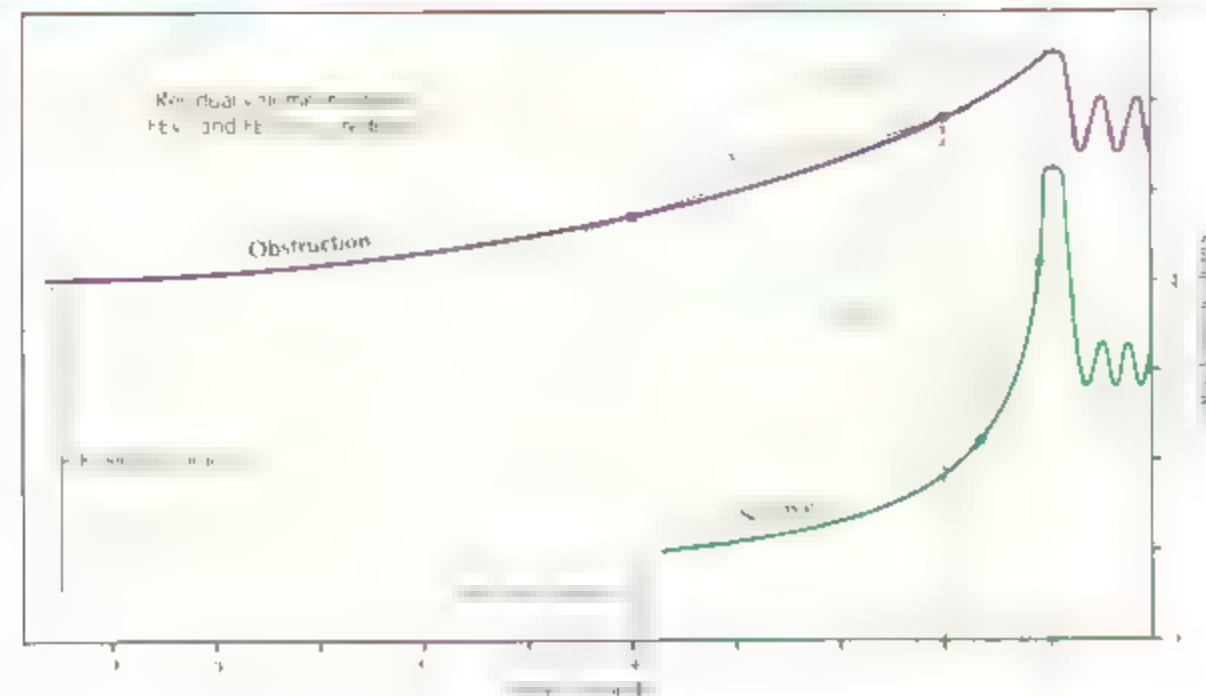
 ... the ventilatory rate increases ...

... ...

Centriacinar
Centrilobular
Emphysema



FIGURE 5.25 OBSTRUCTIVE DISEASE: EMPHYSEMA



Maximum Expiratory Flow-Volume Curves

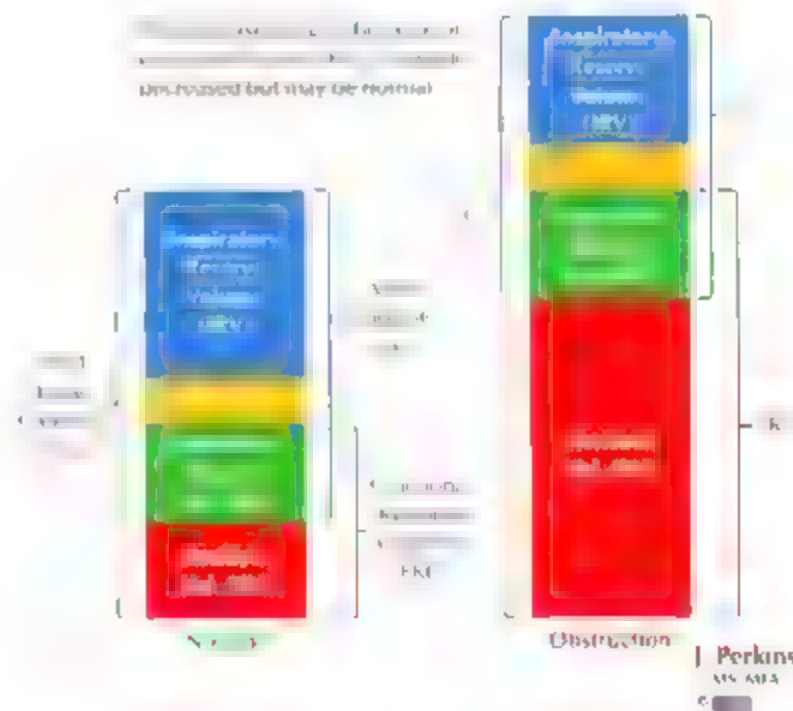
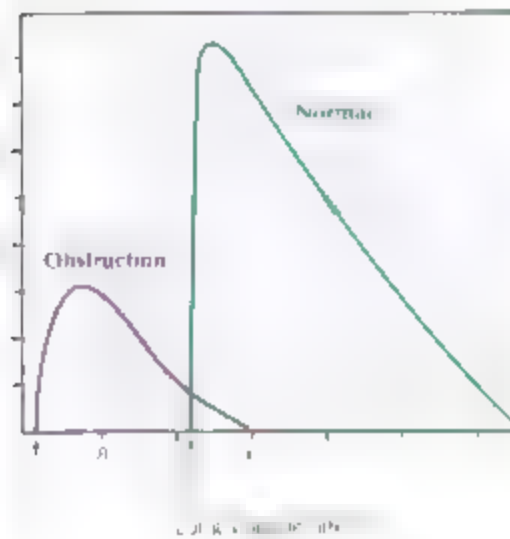


FIGURE 5.26 OBSTRUCTIVE LUNG DISEASE

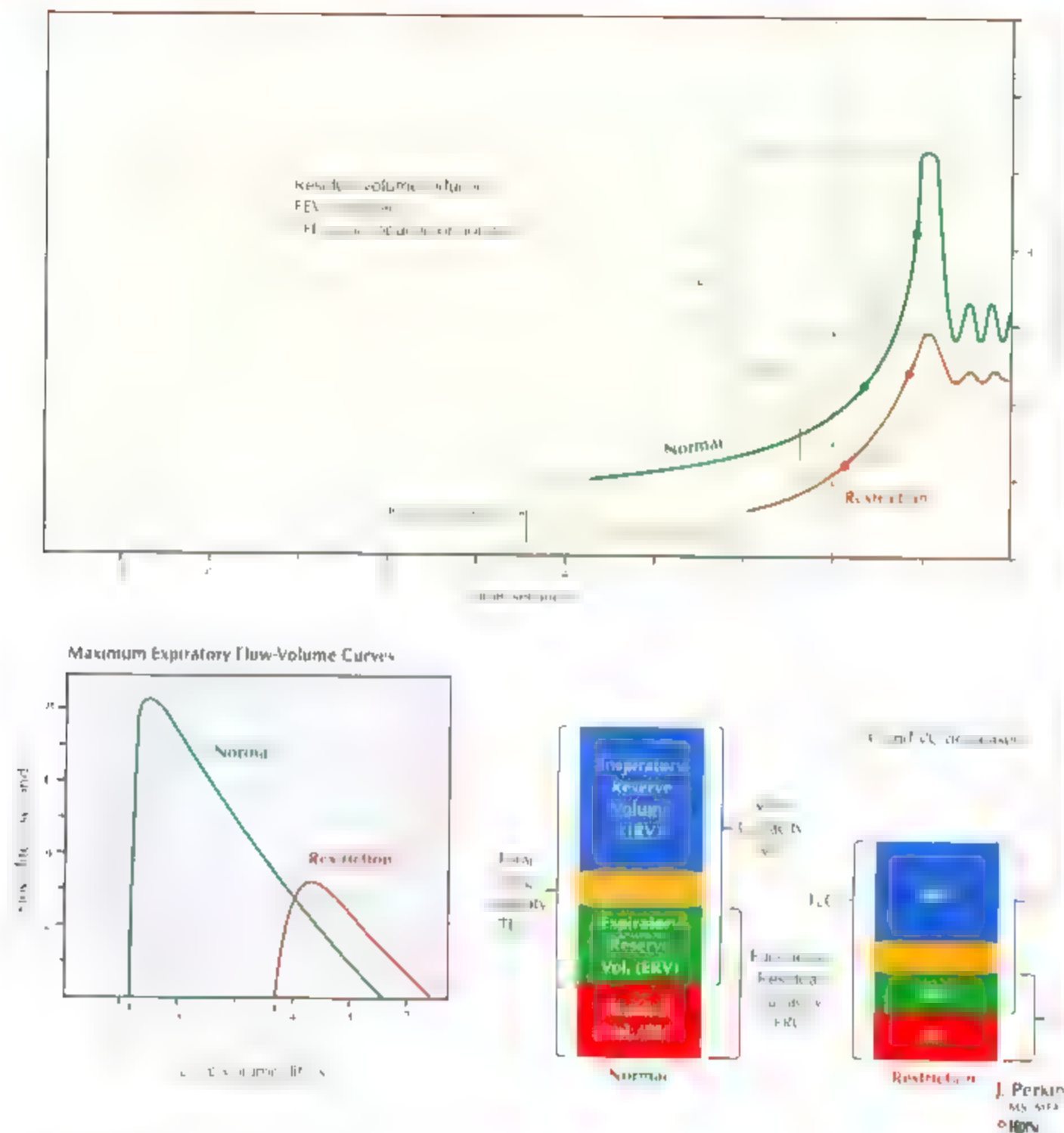


FIGURE 5.27 RESTRICTIVE PULMONARY DISEASE

Restrictive pulmonary disease refers to a group of disorders that result in a decrease in the normal expansion of the lungs, either due to a decrease in lung compliance or an increase in the chest wall stiffness. The increased connective tissue reduces lung compliance, making it increasingly difficult to expand the lung during inspiration. As a result, virtually all lung volumes are reduced. In particular, as shown here, there can be marked decreases in T_L

and VC (measured as T_L or T_L + ERV + IRV). The forced expiratory volume in one second (FEV_1) is decreased in proportion to VC , so the ratio of FEV_1/VC is generally normal. If VC is markedly decreased, this ratio may even increase.

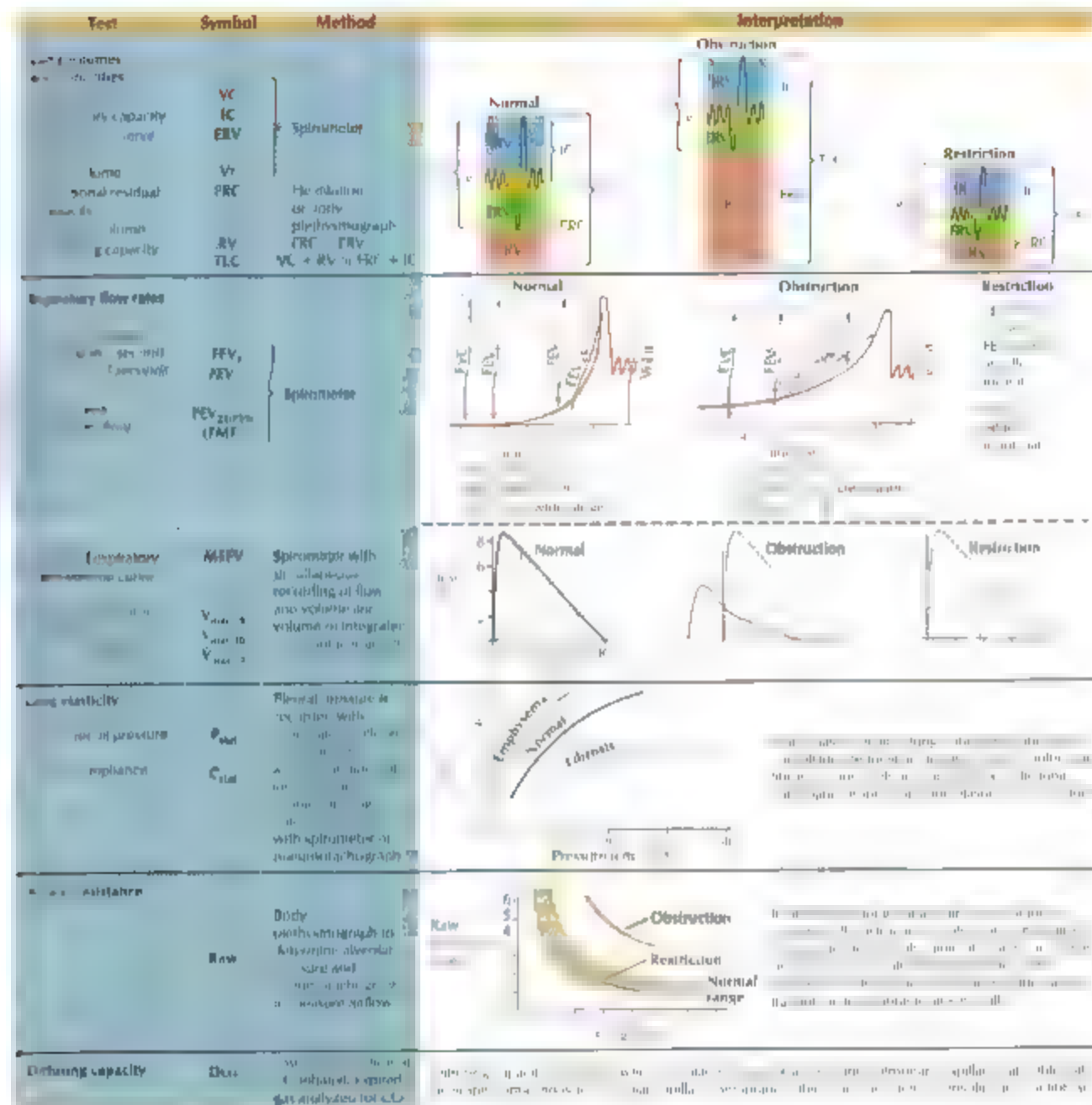


FIGURE 5.28 TESTS OF PULMONARY FUNCTION

VC = Total lung capacity; IC = Inspiratory capacity; ERV = Expiratory reserve volume; VT = Tidal volume; FRC = Functional residual capacity; RV = Residual volume; TLC = Total lung capacity; FEV₁ = First expiratory volume; FEV₂₅₋₇₅ = Expiratory volume in 25-75% of expiration; FEV₂₅₋₇₅ (FME) = Functional residual capacity; T_{exp} = Expiratory time constant; P_{exp} = Expiratory pressure; C_{exp} = Expiratory compliance; Raw = Raw resistance; DLCO = Diffusing capacity of the lung for carbon monoxide.

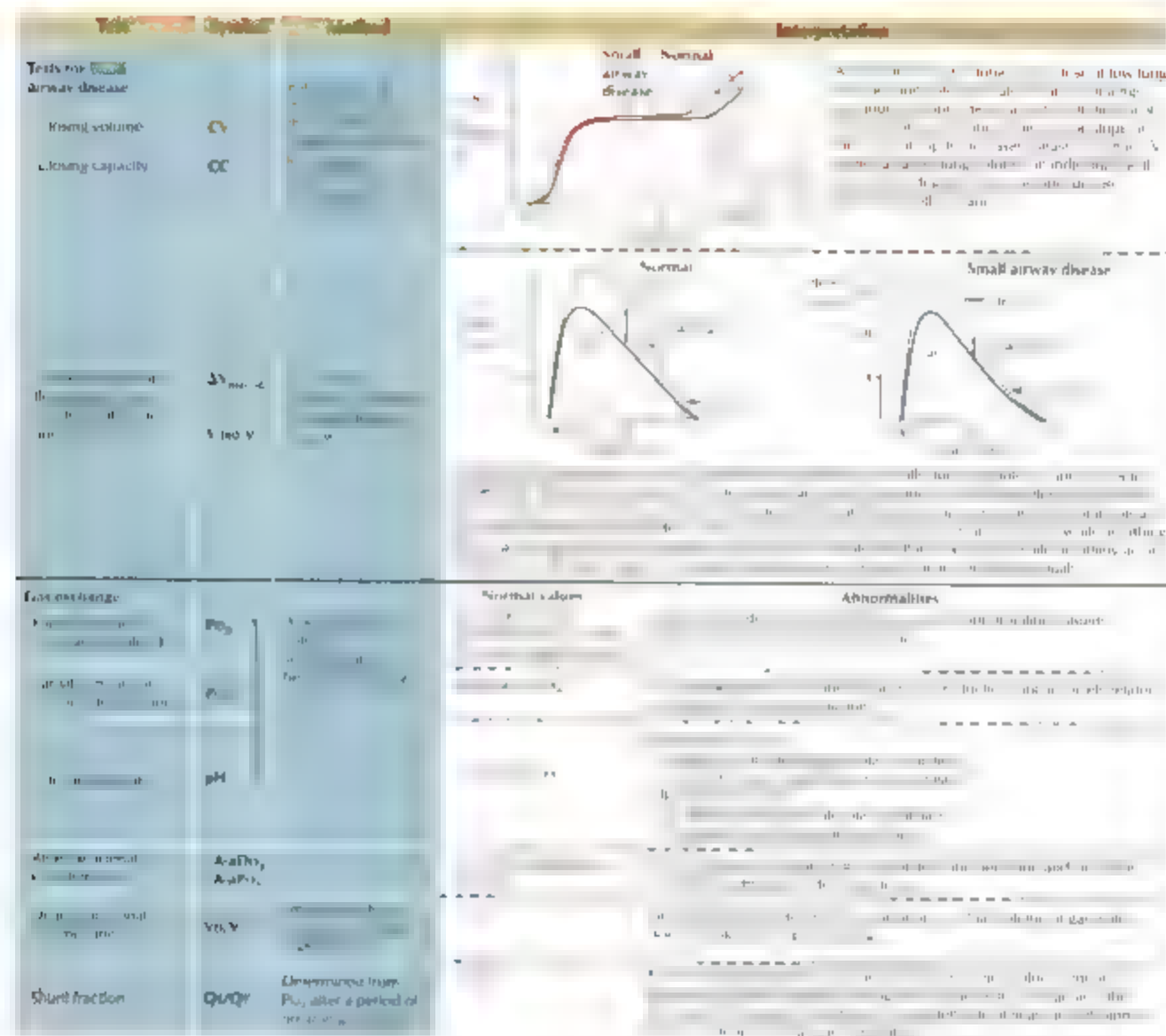


FIGURE 5.28 TESTS OF PULMONARY FUNCTION—CONT'D

This figure illustrates the normal and abnormal values for the various pulmonary function tests. The normal values are shown in the left column, and the abnormal values are shown in the right column.

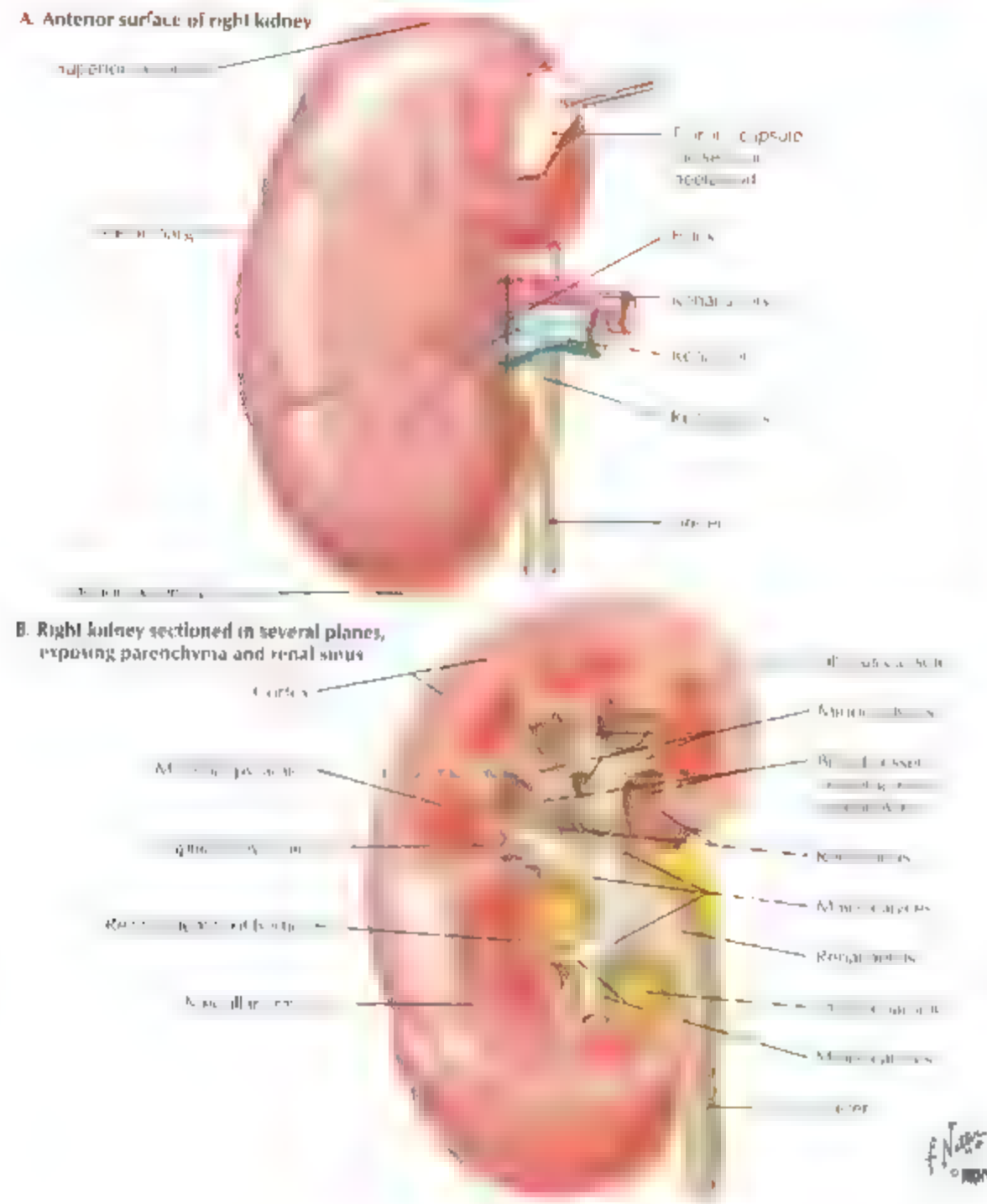


FIGURE 6.1 ANATOMY OF THE KIDNEY

The kidneys are bean-shaped organs that sit on either side of the vertebral column, just below the diaphragm. The left kidney is slightly higher than the right kidney because of the liver's position on the right side of the body. The kidneys are retroperitoneal, meaning they are located behind the peritoneum. The kidneys are responsible for filtering blood, removing waste and excess fluid, and regulating blood pressure. The kidneys also produce hormones that regulate calcium levels and red blood cell production. The kidneys are composed of two main parts: the renal cortex and the renal medulla. The renal cortex is the outer layer of the kidney, and the renal medulla is the inner layer. The renal medulla is divided into renal pyramids, which are triangular in shape. The renal pyramids are separated by renal columns. The renal pelvis is a funnel-shaped structure that collects urine from the renal pyramids and drains it into the ureter. The renal sinus is the space inside the kidney that contains the renal pelvis and the renal pyramids. The renal sinus is filled with renal sinus fat, which helps to cushion the kidney and regulate its temperature. The renal artery and renal vein enter the kidney at the hilum, which is the indentation on the medial side of the kidney. The renal artery carries oxygenated blood to the kidney, and the renal vein carries deoxygenated blood away from the kidney.

The renal cortex is the outer layer of the kidney, and the renal medulla is the inner layer. The renal medulla is divided into renal pyramids, which are triangular in shape. The renal pyramids are separated by renal columns. The renal pelvis is a funnel-shaped structure that collects urine from the renal pyramids and drains it into the ureter. The renal sinus is the space inside the kidney that contains the renal pelvis and the renal pyramids. The renal sinus is filled with renal sinus fat, which helps to cushion the kidney and regulate its temperature. The renal artery and renal vein enter the kidney at the hilum, which is the indentation on the medial side of the kidney. The renal artery carries oxygenated blood to the kidney, and the renal vein carries deoxygenated blood away from the kidney.

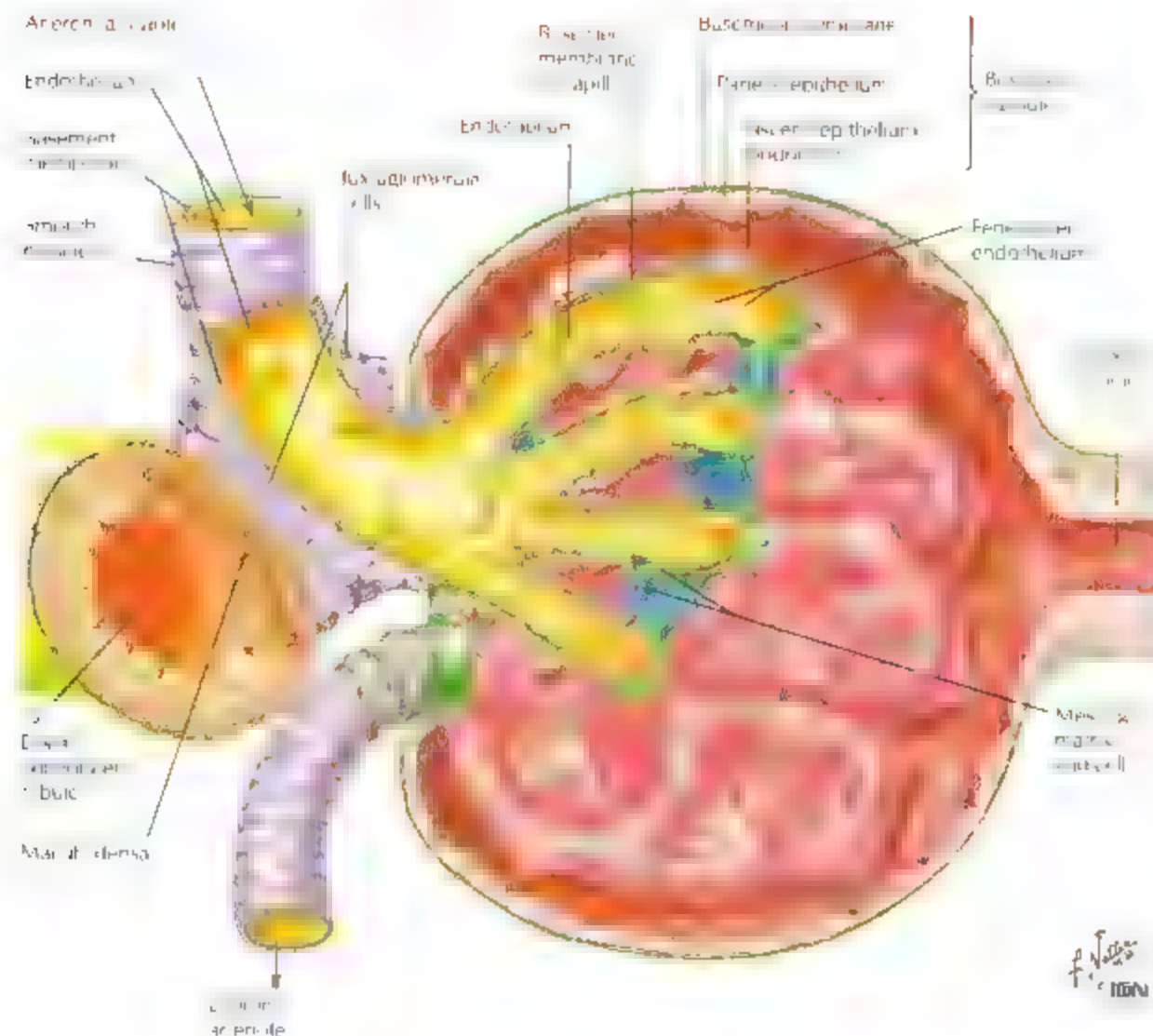


FIGURE 6.3 ANATOMY OF THE GLOMERULUS

The glomerulus is a cluster of capillaries. The afferent arteriole enters the glomerulus and the efferent arteriole exits. The glomerulus is surrounded by the Bowman's capsule, which consists of an inner layer of fenestrated endothelium and an outer layer of parietal epithelium, separated by a basement membrane. The space between these layers is the Bowman's space. The macula densa is a specialized region of the distal tubule that is in contact with the glomerulus. The distal tubule and proximal tubule are part of the renal tubule system.

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ultrafiltrate of plasma is produced at the glomerulus. It is driven out of the capillary at pressure ΔP which is the difference between the glomerular capillary pressure and the sum of the oncotic pressure of the glomerular capillary and the hydrostatic pressure of Bowman's capsule. ΔP is relatively constant despite variations in blood pressure because of the autoregulation of the glomerular capillary pressure.

are responsible for physiologic regulation of the CFR. Although sympathetic nerves innervate the afferent arterioles, regulating intracapillary hydrostatic pressure and thus the CFR. Although not shown, increased delivery of NaCl to the proximal tubule stimulates the CFR, whereas distal tubule reabsorption of NaCl and water decreases the CFR. Angiotensin II also increases the CFR. Atrial natriuretic peptide and prostaglandins have opposite effects and increase the CFR. Atrial natriuretic peptide and prostaglandins have opposite effects and increase the CFR.

Clearance principle

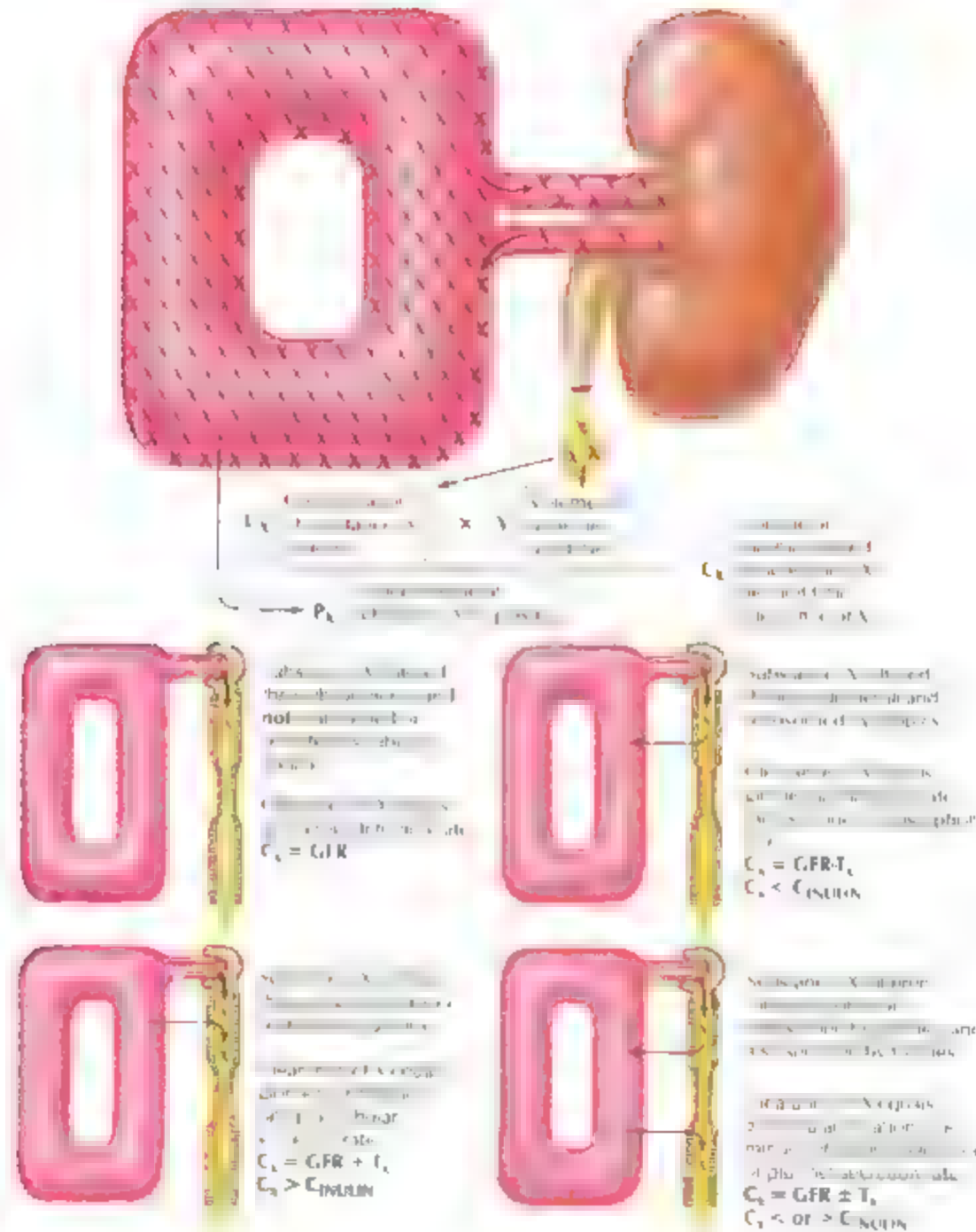


FIGURE 6.5 RENAL CLEARANCE

The renal clearance of a substance provides information about how the substance is handled by the kidney. The clearance of a substance is defined as the volume of plasma from which the substance is completely removed in a given time. The clearance of a substance is equal to the glomerular filtration rate (GFR) if the substance is only filtered and not reabsorbed or secreted. If the substance is reabsorbed, the clearance is less than the GFR. If the substance is secreted, the clearance is greater than the GFR.

If a substance is only filtered, then its clearance is equal to the GFR. If a substance is reabsorbed, then its clearance is less than the GFR. If a substance is secreted, then its clearance is greater than the GFR. The clearance of a substance is a useful measure of the kidney's ability to filter and excrete substances.

PRINCIPLE OF TUBULAR REABSORPTION LIMITATION (T_m) USING GLUCOSE AS EXAMPLE

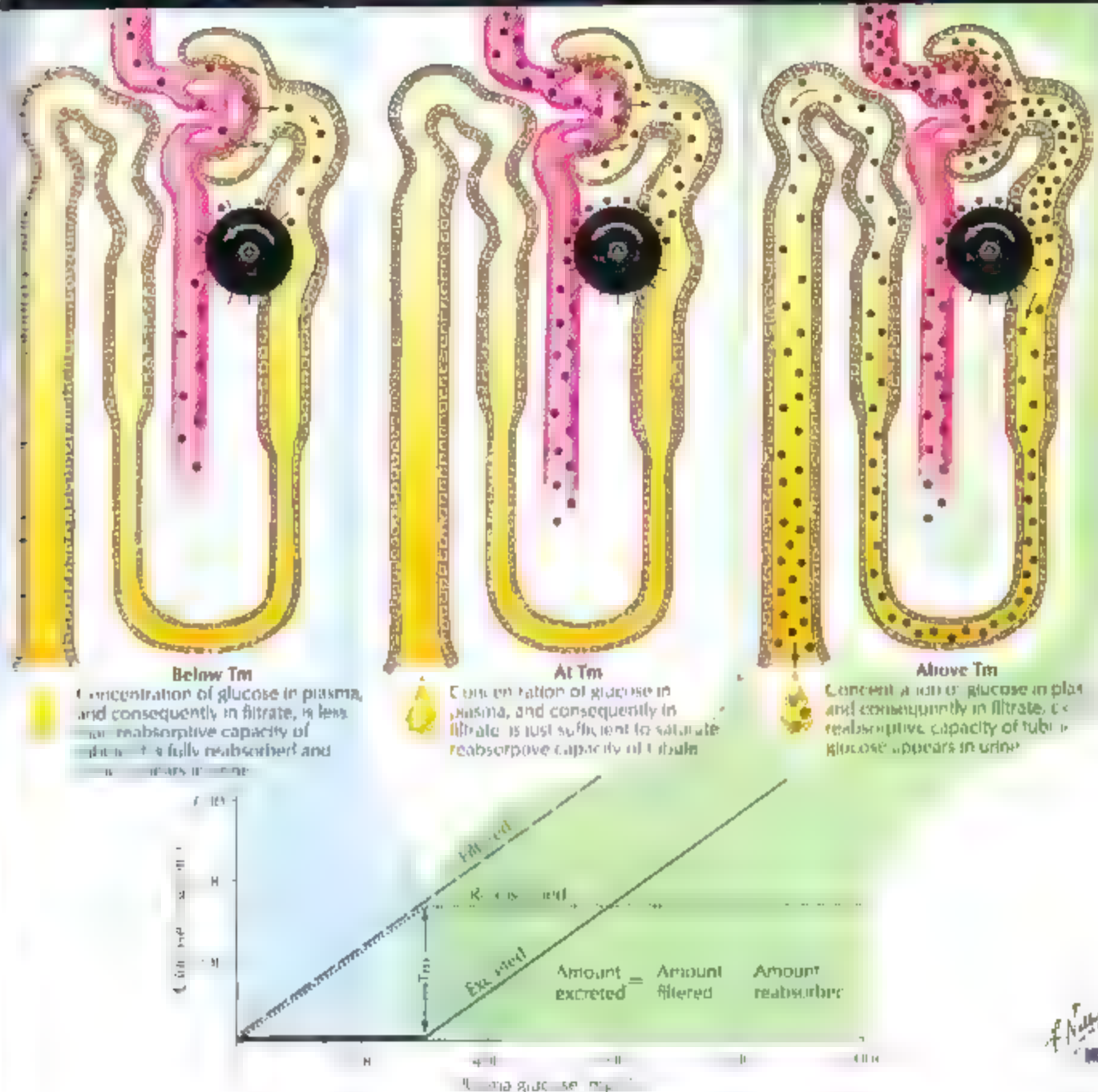


FIGURE 6.6 RENAL HANDLING OF GLUCOSE

is filtered at the glomerulus and reabsorbed by the proximal tubule. Normally, no glucose appears in the urine because all of the glucose is reabsorbed. However, if the plasma concentration of glucose is increased, as it is in diabetes mellitus, glucose

appears in the urine. Therefore, the renal clearance of glucose will increase as the plasma concentration of glucose increases.

PRINCIPLE OF TUBULAR SECRETION LIMITATION (T_m) USING PARA-AMINOHIPPURATE (PAH) AS EXAMPLE

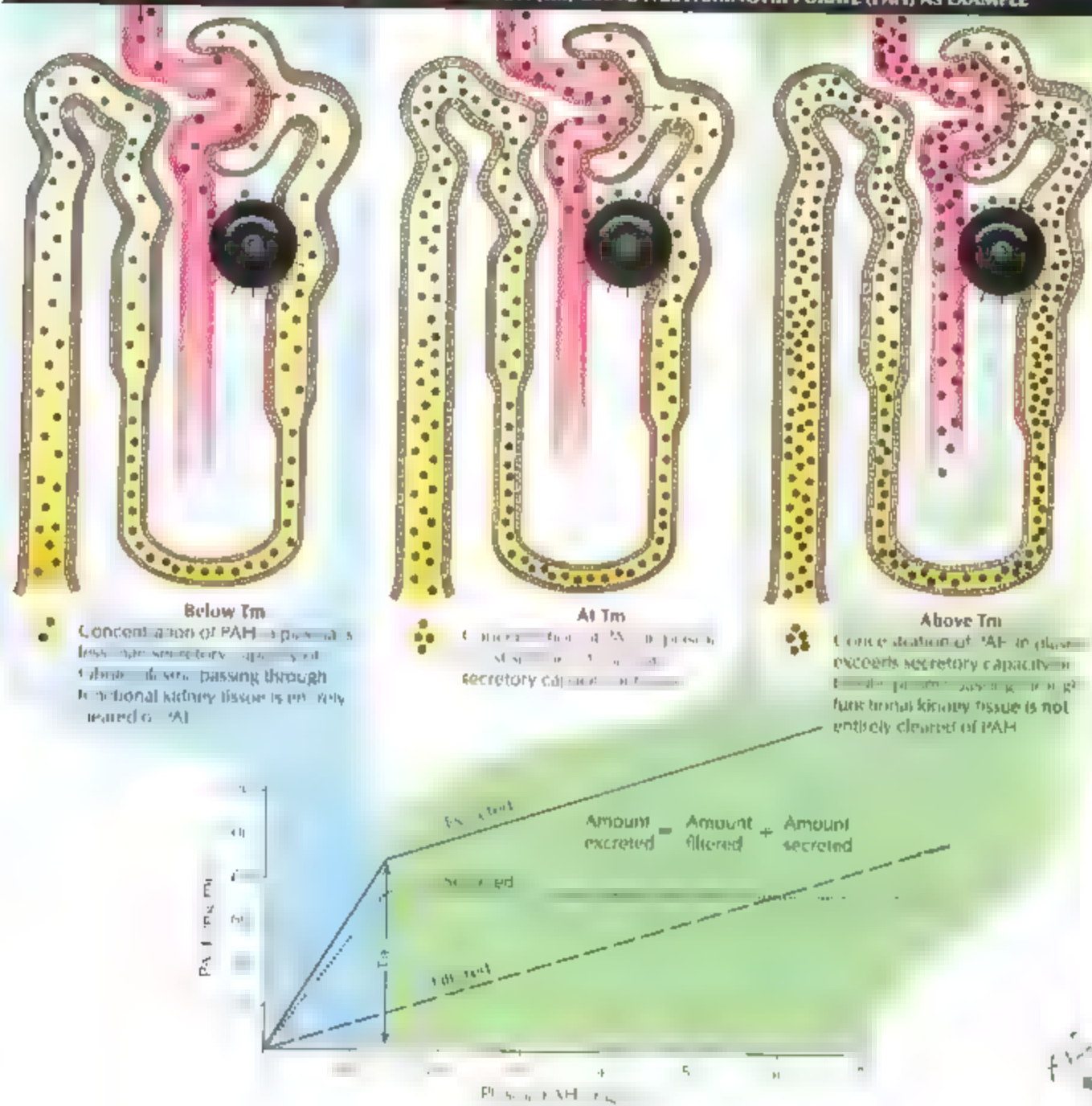


FIGURE 6.7 RENAL HANDLING OF PARA-AMINO HIPPURATE (PAH)

A low plasma concentration of PAH results in a low rate of excretion. As the plasma concentration of PAH increases, the rate of excretion increases. At a high plasma concentration, the rate of excretion is constant.

PAH approximates the renal plasma flow. As the plasma concentration of PAH increases, the rate of excretion increases. At a high plasma concentration, the rate of excretion is constant and the renal clearance of PAH increases.

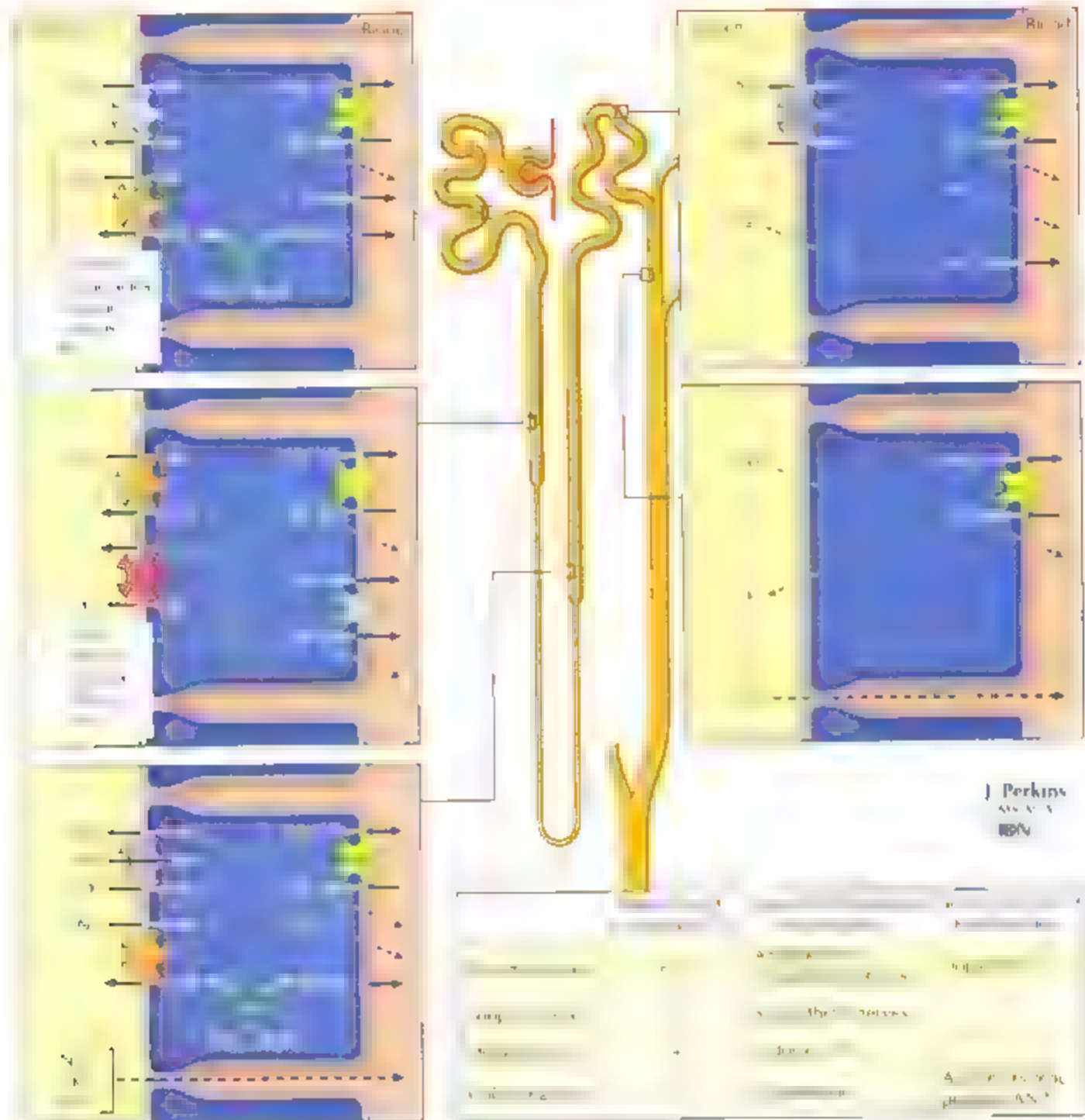


FIGURE 6.8 RENAL Na⁺ REABSORPTION

Reabsorption of Na⁺ in the proximal convoluted tubule is the most important site for Na⁺ reabsorption.

Reabsorption of Na⁺ in the thick ascending loop of Henle is the most important site for Na⁺ reabsorption.

Reabsorption of Na⁺ in the distal convoluted tubule is the most important site for Na⁺ reabsorption.

Reabsorption of Na⁺ in the collecting duct is the most important site for Na⁺ reabsorption.

MECHANISM OF ANTIDIURETIC HORMONE IN REGULATING URINE VOLUME AND CONCENTRATION

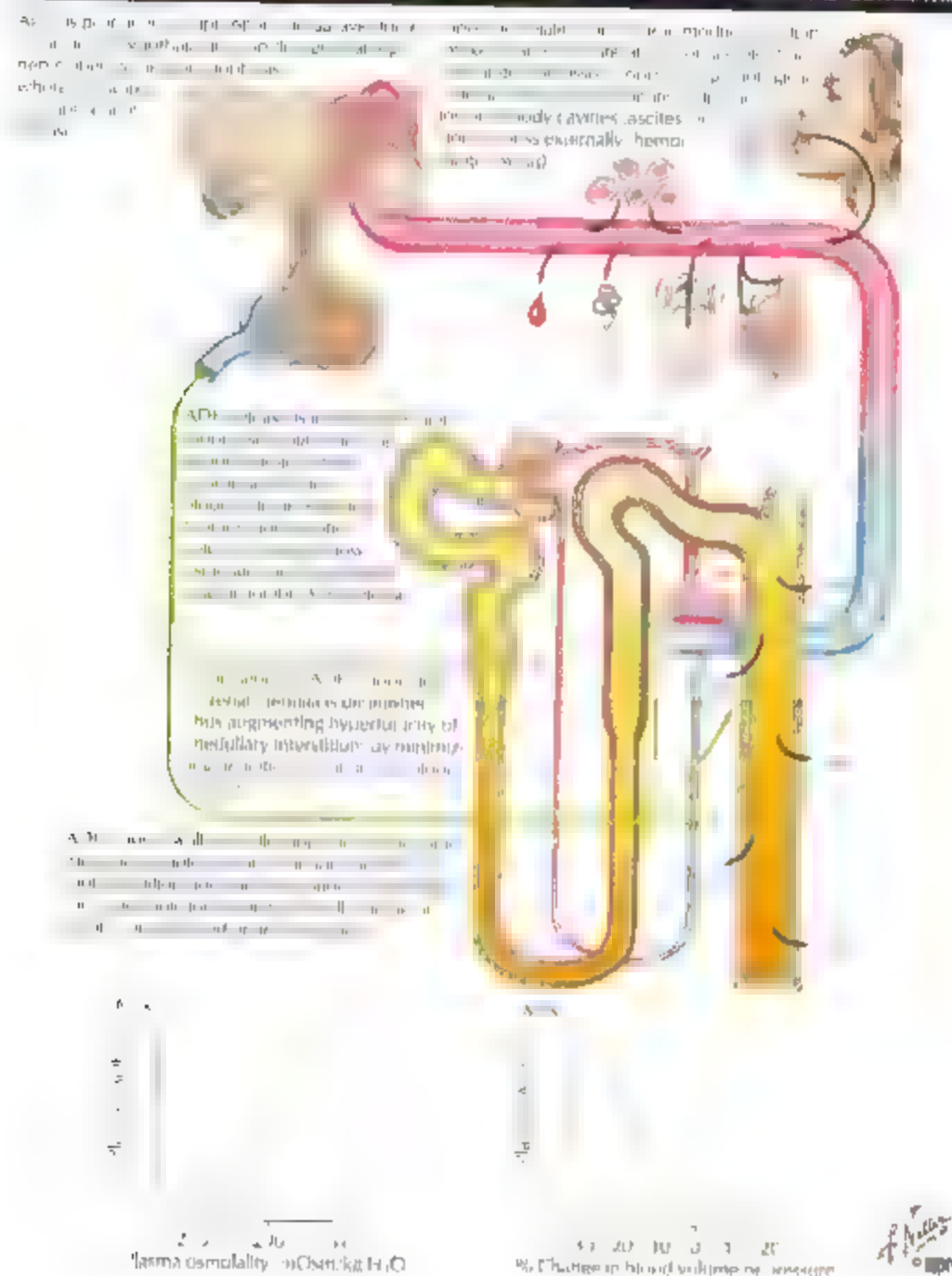


FIGURE 6.9 ADH SECRETION AND ACTION

ADH regulates the volume of water excreted by the kidneys. Its secretion is regulated by the osmolality of the body fluids and the volume of blood. Decreases in blood volume and pressure of 10% to 15% or more are

needed to effect ADH secretion. The blood volume and pressure sensors are found in the large pulmonary vessels, the carotid sinus, and the aortic arch. These sensors respond to changes in blood volume and pressure by secreting ADH.

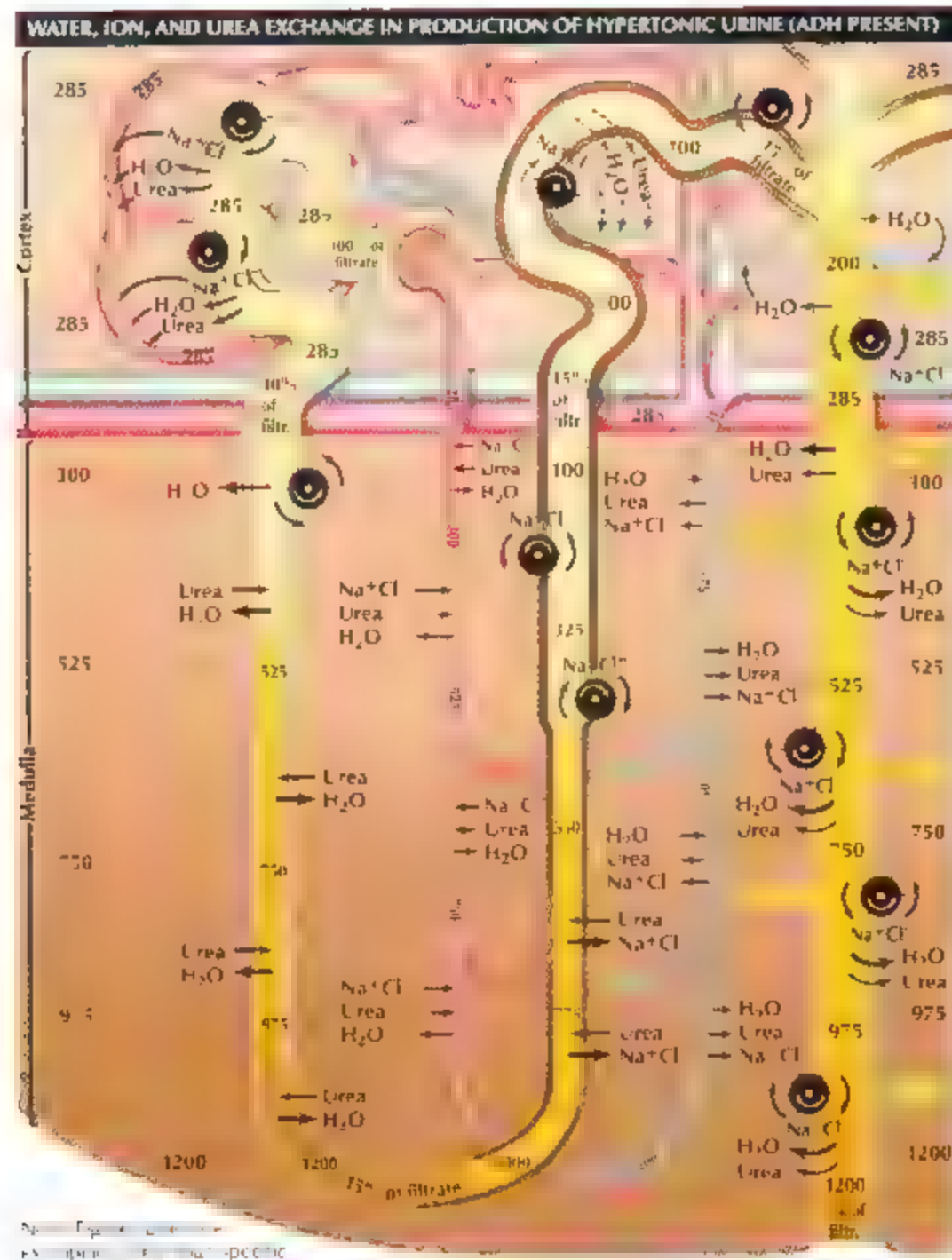


FIGURE 6.10 CONCENTRATION OF THE URINE

The diagram illustrates the countercurrent multiplier system in the kidney, showing the exchange of water, NaCl, and urea in the cortex and medulla. The osmolarity values are indicated at various points along the nephron and in the surrounding tissue. The proximal convoluted tubule (PCT) reabsorbs 100% of filtrate. The distal convoluted tubule (DCT) reabsorbs NaCl and urea. The loop of Henle (LOH) descends into the medulla, reabsorbing NaCl and urea. The collecting duct (CD) reabsorbs water (H₂O) and urea, facilitated by ADH. Urea is reabsorbed in the PCT and DCT, and secreted in the LOH and CD. This creates a high concentration of urea in the medulla, which drives water reabsorption in the CD. ADH (Antidiuretic Hormone) is present in the medulla, facilitating water reabsorption in the CD.

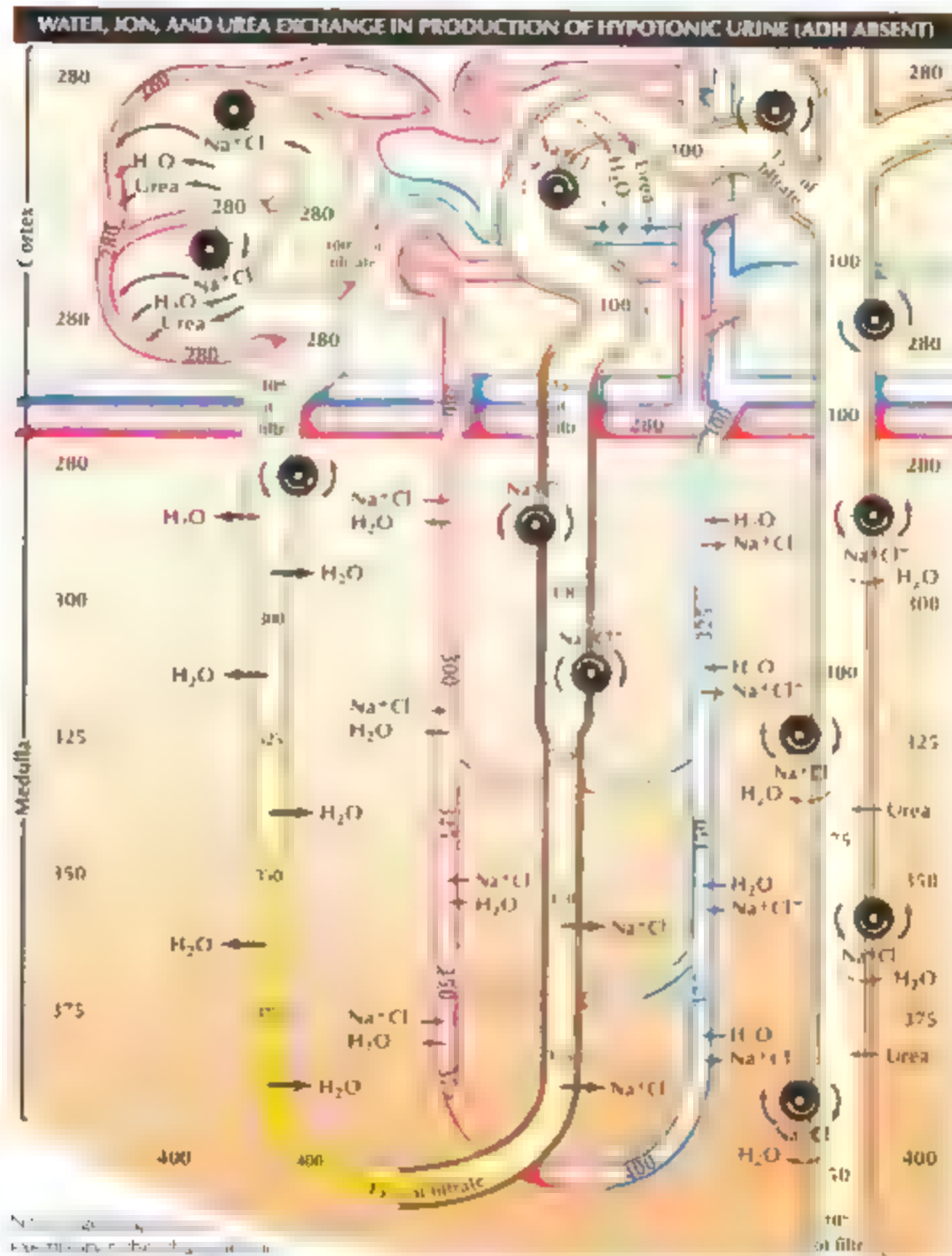


FIGURE 6.11 DILUTION OF THE URINE

The kidney is able to produce a wide range of urine osmolarities, from 100 to 1200 mOsm/L. This is achieved by the countercurrent multiplier system in the kidney medulla. The collecting duct is impermeable to water, while the distal tubule and thin ascending loop of Henle are permeable. Osmolarity increases from 280 in the cortex to 400 in the inner medulla. Water is reabsorbed from the distal tubule and thin ascending loop, while Na^+ and Cl^- are reabsorbed from the thick ascending loop. Urea is reabsorbed from the collecting duct. The final urine is hypotonic (100) because water is lost from the collecting duct.

The kidney is able to produce a wide range of urine osmolarities, from 100 to 1200 mOsm/L. This is achieved by the countercurrent multiplier system in the kidney medulla. The collecting duct is impermeable to water, while the distal tubule and thin ascending loop of Henle are permeable. Osmolarity increases from 280 in the cortex to 400 in the inner medulla. Water is reabsorbed from the distal tubule and thin ascending loop, while Na^+ and Cl^- are reabsorbed from the thick ascending loop. Urea is reabsorbed from the collecting duct. The final urine is hypotonic (100) because water is lost from the collecting duct.



both. The renin-angiotensin system acts to regulate intracellular electrolyte balance, especially sodium. Changes in intracellular sodium levels are detected by the kidneys, which then release renin. Renin converts angiotensinogen to angiotensin I, which is then converted to angiotensin II. Angiotensin II stimulates the release of aldosterone from the adrenal cortex, which then acts to increase sodium reabsorption in the kidneys.

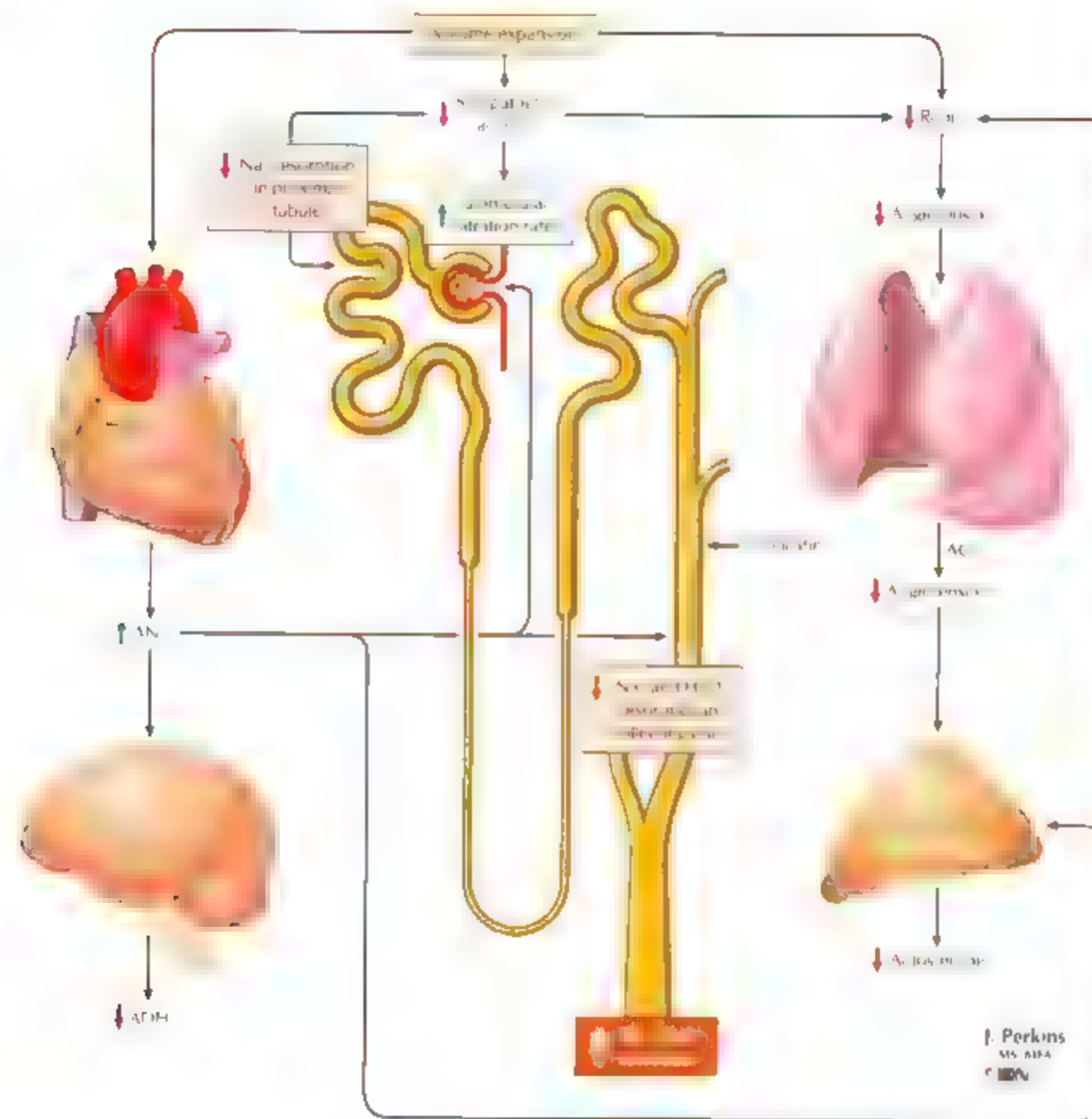


FIGURE 6.13 RESPONSE TO VOLUME EXPANSION

The kidneys respond to an increase in the volume of the extracellular fluid volume expansion by increasing their excretion of Na^+ and water. The neural mechanisms in this response are shown above. Enhanced Na^+ excretion results from a decrease in the interest for an increase in reabsorption of Na^+ and water in the distal tubule and collecting duct. This occurs because the sympathetic nervous system is suppressed and aldosterone and angiotensin II secretion systems are suppressed and atrial natriuretic

peptide and ANP secretion is stimulated. It occurs because ANP inhibits the renin-angiotensin-aldosterone system. ANP also inhibits the sympathetic nervous system. For the kidneys to excrete more Na^+ and water, the distal tubule and collecting duct must be able to reabsorb less Na^+ and water. This occurs because decreased levels of aldosterone and angiotensin II cause decreased levels of Na^+ and water reabsorption. Also, decreased levels of ADH cause decreased levels of water reabsorption. Aldosterone and angiotensin II are secreted by the adrenal cortex.

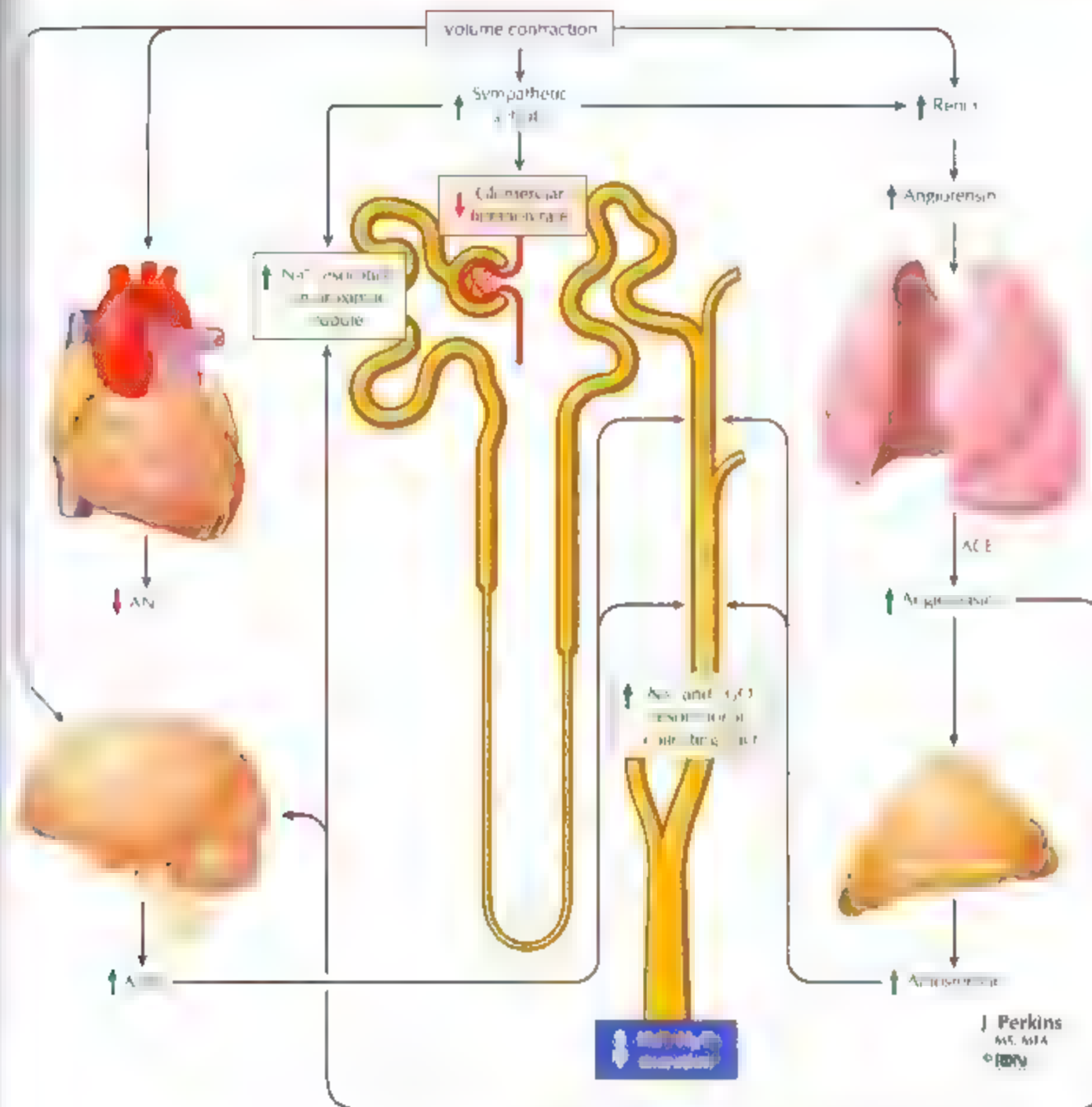
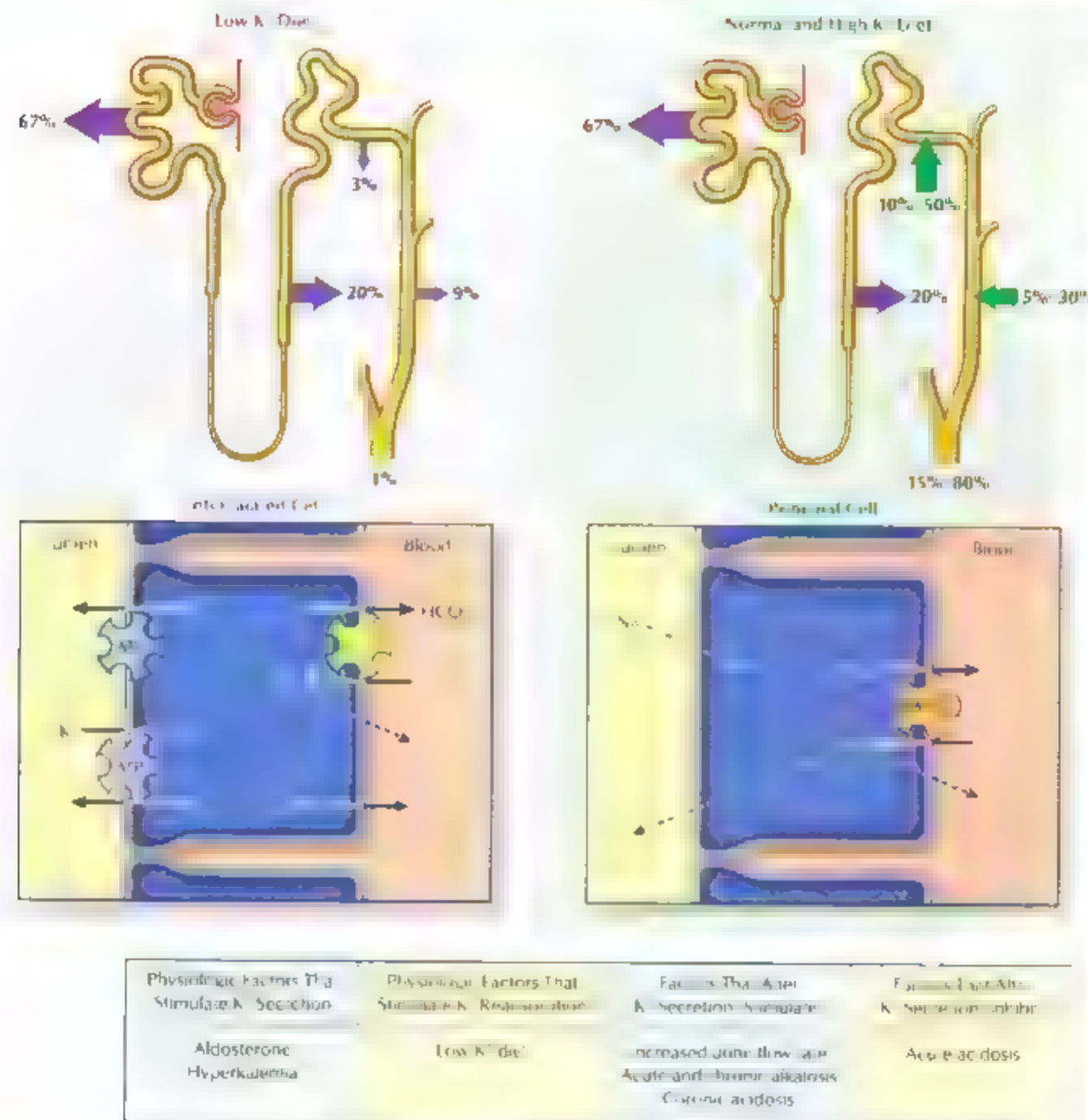


FIGURE 6.14 RESPONSE TO VOLUME CONTRACTION

volume contraction, a decrease in the volume of the extracellular fluid is maintained by decreasing the excretion of Na⁺ and H₂O. The primary mechanisms in this response are summarized in Table 6.1. Na⁺ excretion is decreased by a decrease in GFR, an increase in reabsorption of Na⁺ in the proximal tubule, and stimulation of Na⁺ reabsorption along the distal tubule and collecting duct. Sympathetic and renin-angiotensin systems are activated in a volume contraction.

Angiotensin II increases the secretion of aldosterone and ADH. Aldosterone increases Na⁺ reabsorption in the distal tubule and collecting duct. ADH increases water reabsorption in the collecting duct. Angiotensin II also increases the secretion of ANP, which is suppressed. The sympathetic and renin-angiotensin systems also increase the GFR and stimulate the release of renin from the juxtaglomerular cells.

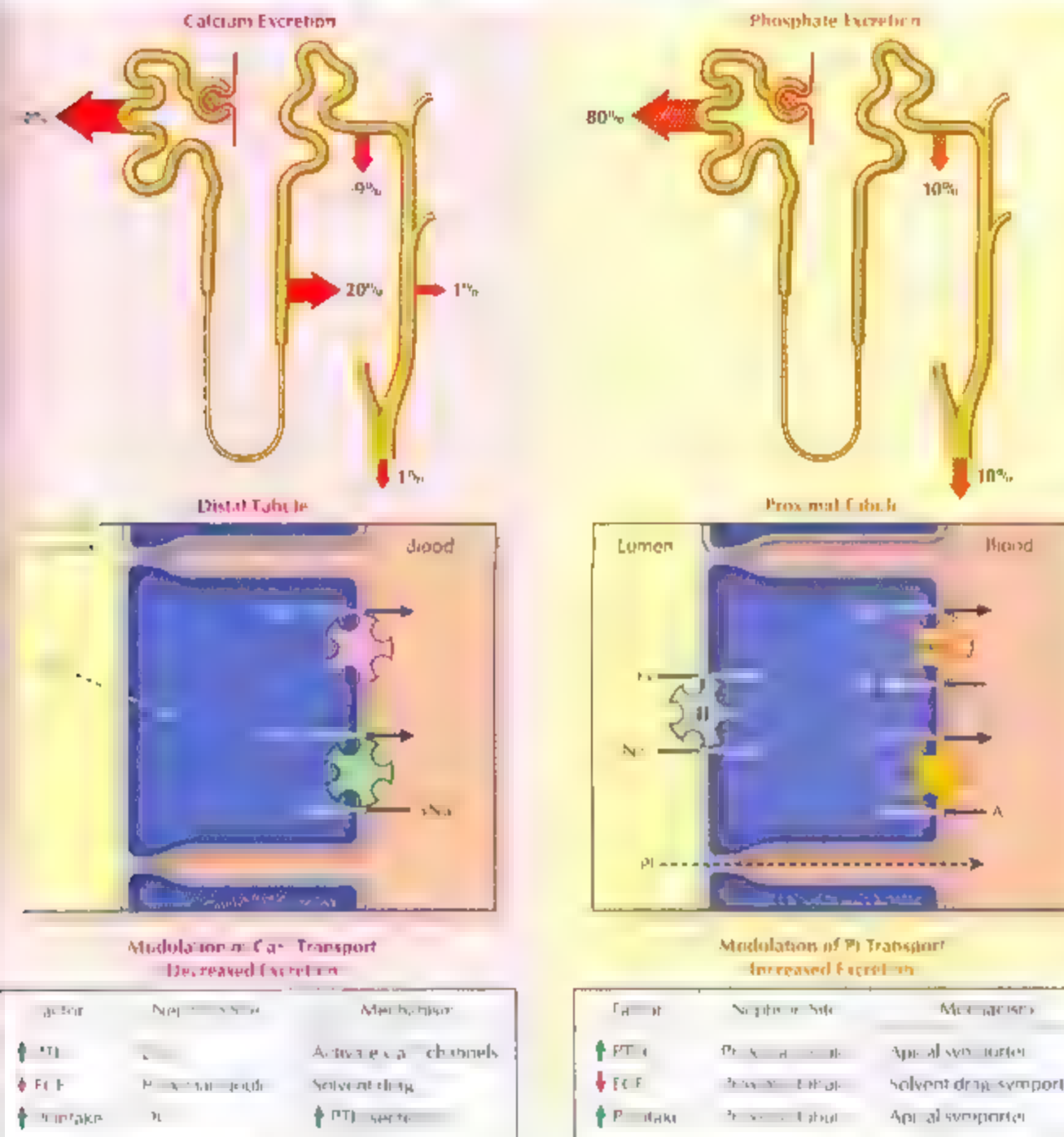


J. Perkins
MS, MFA
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FIGURE 6.15 POTASSIUM EXCRETION

The kidneys are the primary route for excretion of K⁺ in the body, and the amount excreted varies with dietary K⁺ intake. On a low K⁺ diet, only about 1% of the filtered load is excreted. With a normal- or high-K⁺ diet, varying amounts of K⁺ are excreted. Acute or chronic acidosis excreted under these conditions reflects K⁺ that is secreted into the tubular fluid by the collecting duct. The principal cell of the co-

lecting duct secretes K⁺, while the intercalated cell in the collecting duct is involved in K⁺ secretion during chronic acidosis. The mechanisms of K⁺ reabsorption by the proximal tubule, thick ascending limb of Henle loop, and distal tubule are depicted in Figure 6.16. These are not influenced by dietary K⁺.



J Perkins
MS, MBA
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FIGURE 6.16 CALCIUM AND PHOSPHATE EXCRETION

Calcium is absorbed in the entire nephron, its excretion is largely regulated by parathyroid hormone (PTH). PTH acts on the distal tubule to increase calcium reabsorption. Changes in the extracellular fluid calcium level also affect Ca^{2+} excretion. However, the distal tubule is a site of Na^{+} reabsorption by the proximal tubule in response to changes in FGF (see Figure 6.17). PTH secretion is not affected by changes in Na^{+} intake. Phosphate is primarily re-

absorbed by the proximal tubule. Its excretion is also regulated by PTH, which acts on the proximal tubule to inhibit absorption. Changes in the FGF level also affect phosphate excretion. However, like Ca^{2+} , its excretion is also affected by changes in Na^{+} intake. The proximal tubule also reabsorbs P_i in response to changes in FGF, maintaining phosphate balance.

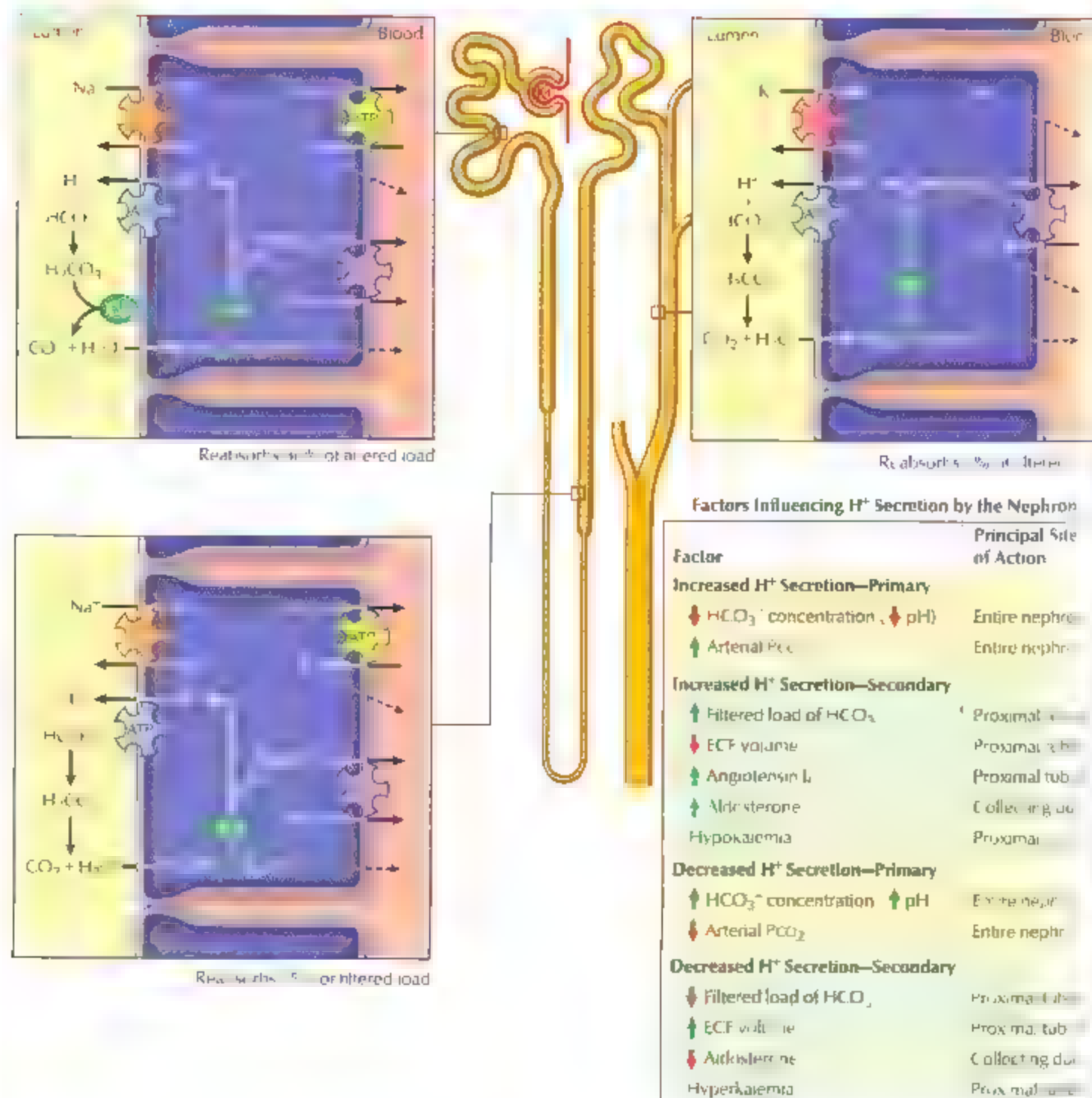


Figure 6.17 HCO_3^- Reabsorption

Bicarbonate is freely filtered and reabsorbed by the process of H^+ secretion along the nephron. Normally, all the filtered HCO_3^- is reabsorbed and none appears in the urine. Changes in systemic acid-base

status alter the rate at which H^+ is secreted, thus altering the amount of HCO_3^- reabsorbed. A number of other factors can also influence the kidney's ability to secrete H^+ and thus reabsorb HCO_3^- .



The kidneys produce new Hct (E) - erythropoietin, which is responsible for the normal, continually generation of new RBCs. It is one of the processes that are controlled by the RAAS. Normally, the production of Hct in the kidneys is regulated (see figure 17). Erythropoietin appears in the urine. It is not always able to produce new RBCs, it simply causes a loss in the body. New Hct is produced when the kidneys excrete Hct. Erythropoietin is the primary hormone in the placenta and during the kidneys' maturation in the NE. Its production and secretion in NE is the most important component in RAAS, because it is

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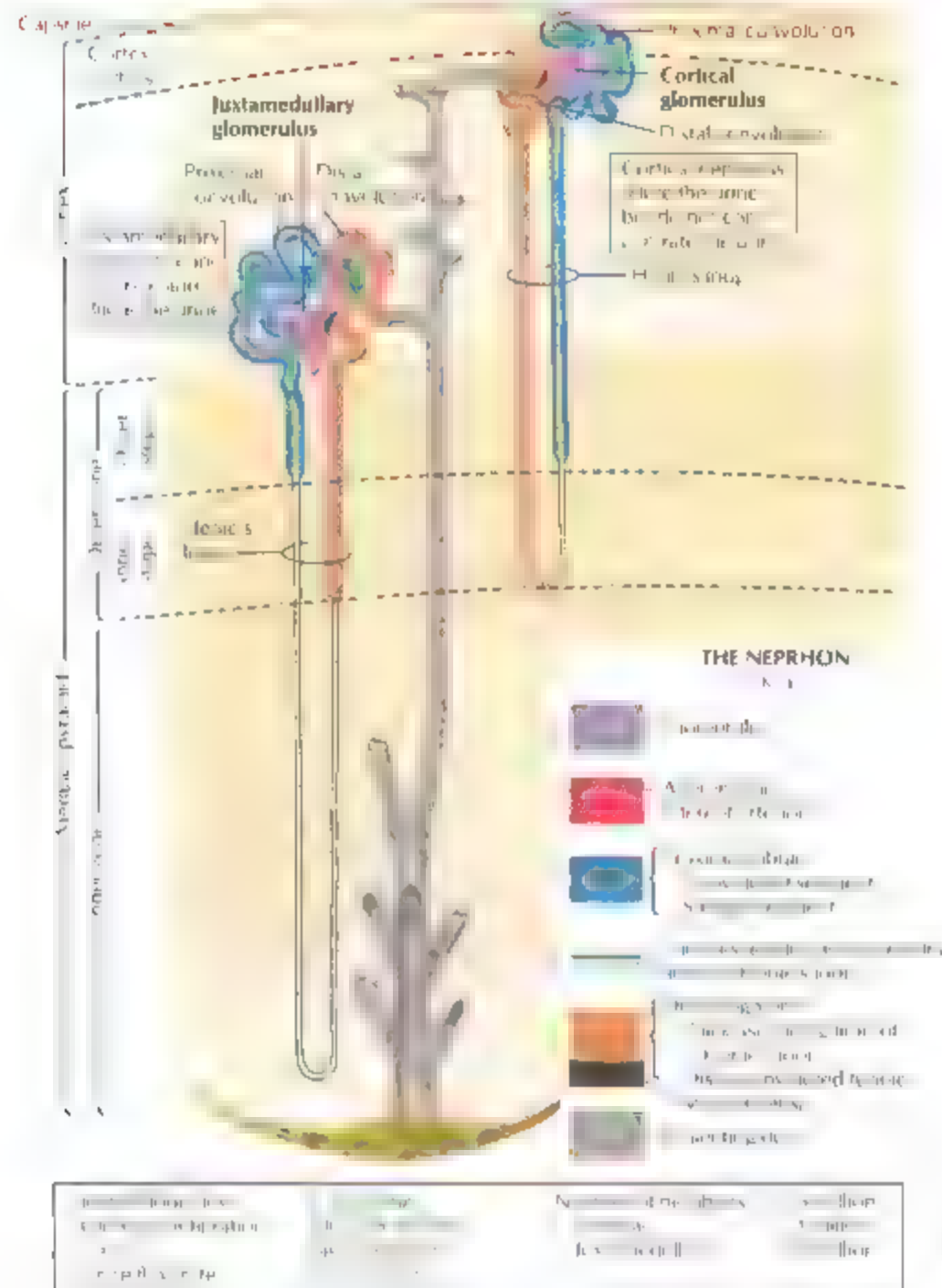


FIGURE 6.2 ANATOMY OF THE NEPHRON

The nephrons of the kidney differ in their structure depending on the location of their glomerulus. Cortical nephrons have their glomeruli near the surface of the cortex. These cortical nephrons have a short loop of Henle that descends only a short distance into the medulla. The juxtamedullary nephrons

are located in the inner medulla. These nephrons have long loops of Henle that extend deep into the inner zone of the medulla. There are also some medullary nephrons.

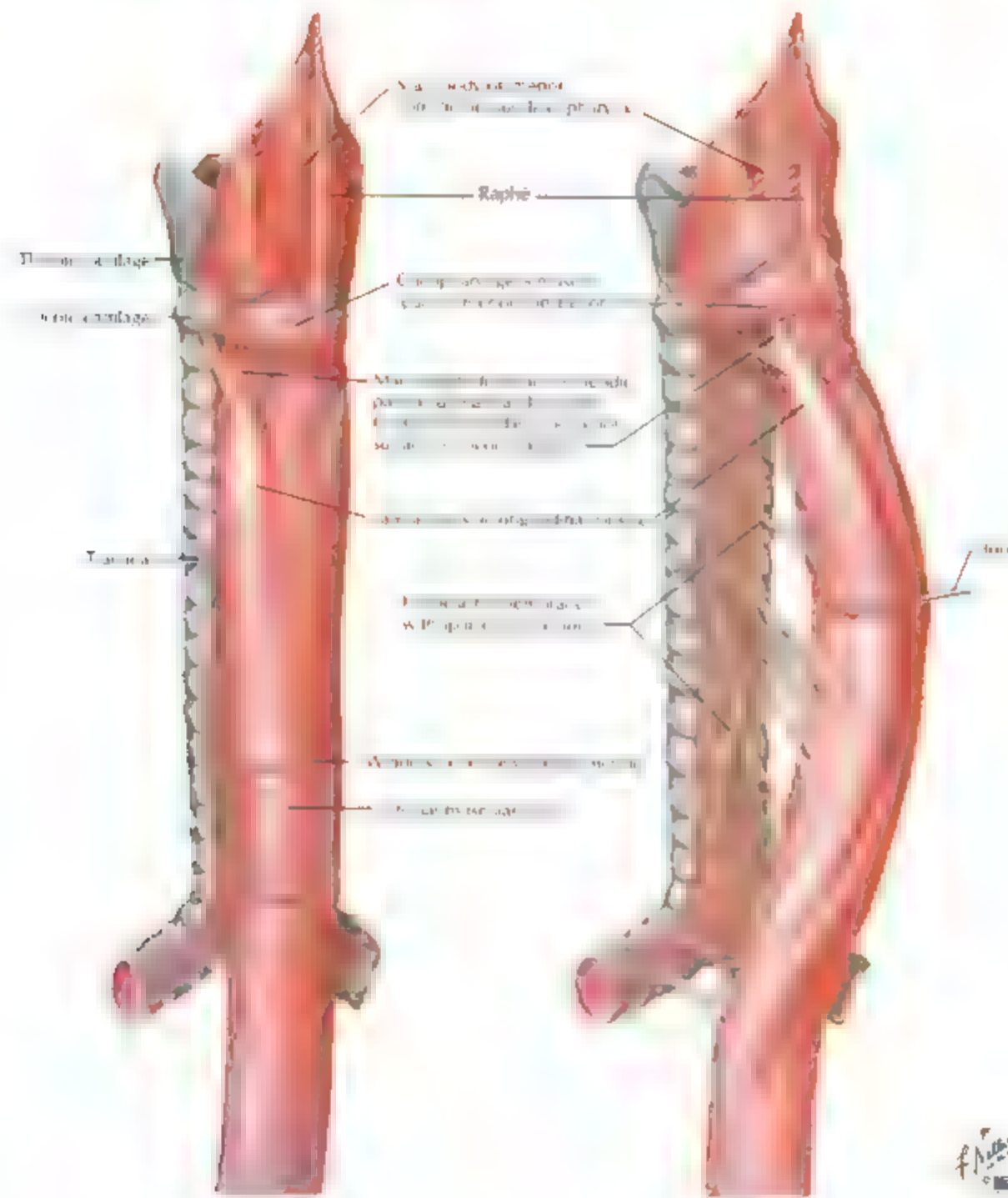


FIGURE 7.1 ESOPHAGUS

The esophagus is posterior to the trachea and extends from the oropharynx to the stomach. It is composed of two parts: the upper third, which is skeletal muscle, and the lower two-thirds, which is smooth muscle.

The esophagus is composed of two parts: the upper third, which is skeletal muscle, and the lower two-thirds, which is smooth muscle. The upper third is composed of skeletal muscle, and the lower two-thirds is composed of smooth muscle.

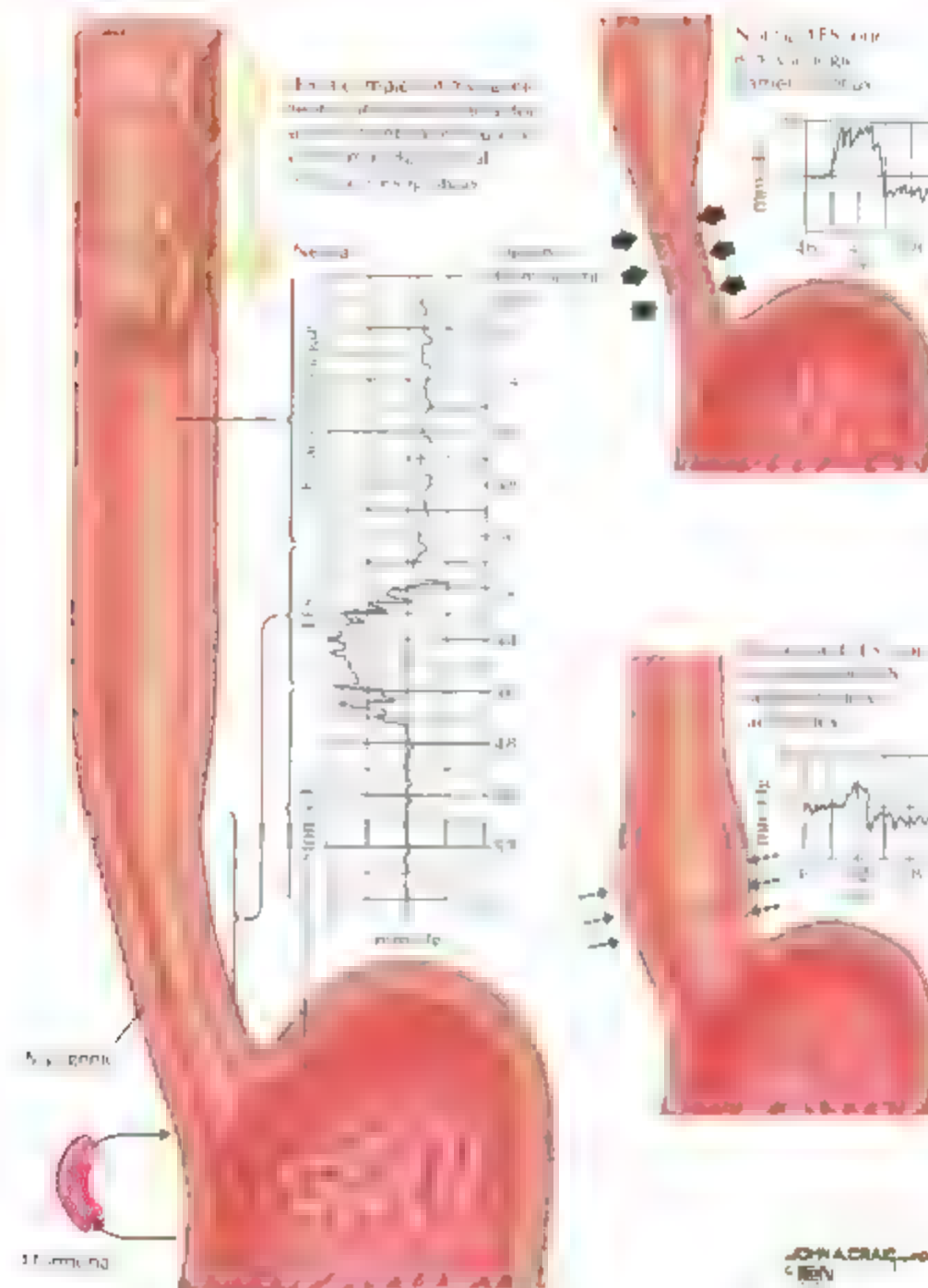


FIGURE 7.3 LOWER ESOPHAGEAL SPHINCTER

Peristalsis is initiated by the swallowing of food, which is followed by the contraction of the esophageal muscles. The LES is a ring of muscle that contracts to prevent the reflux of stomach contents into the esophagus. The LES is normally closed, but it relaxes to allow food to pass into the stomach. The LES is located at the junction of the esophagus and the stomach.

Normally, the LES is closed, and the pressure in the LES is high (10-15 mmHg). When the LES relaxes, the pressure in the LES drops (5-10 mmHg). The pressure in the stomach is normally low (1-2 mmHg). When the LES relaxes, the pressure in the stomach rises (3-4 mmHg). The LES is located at the junction of the esophagus and the stomach.

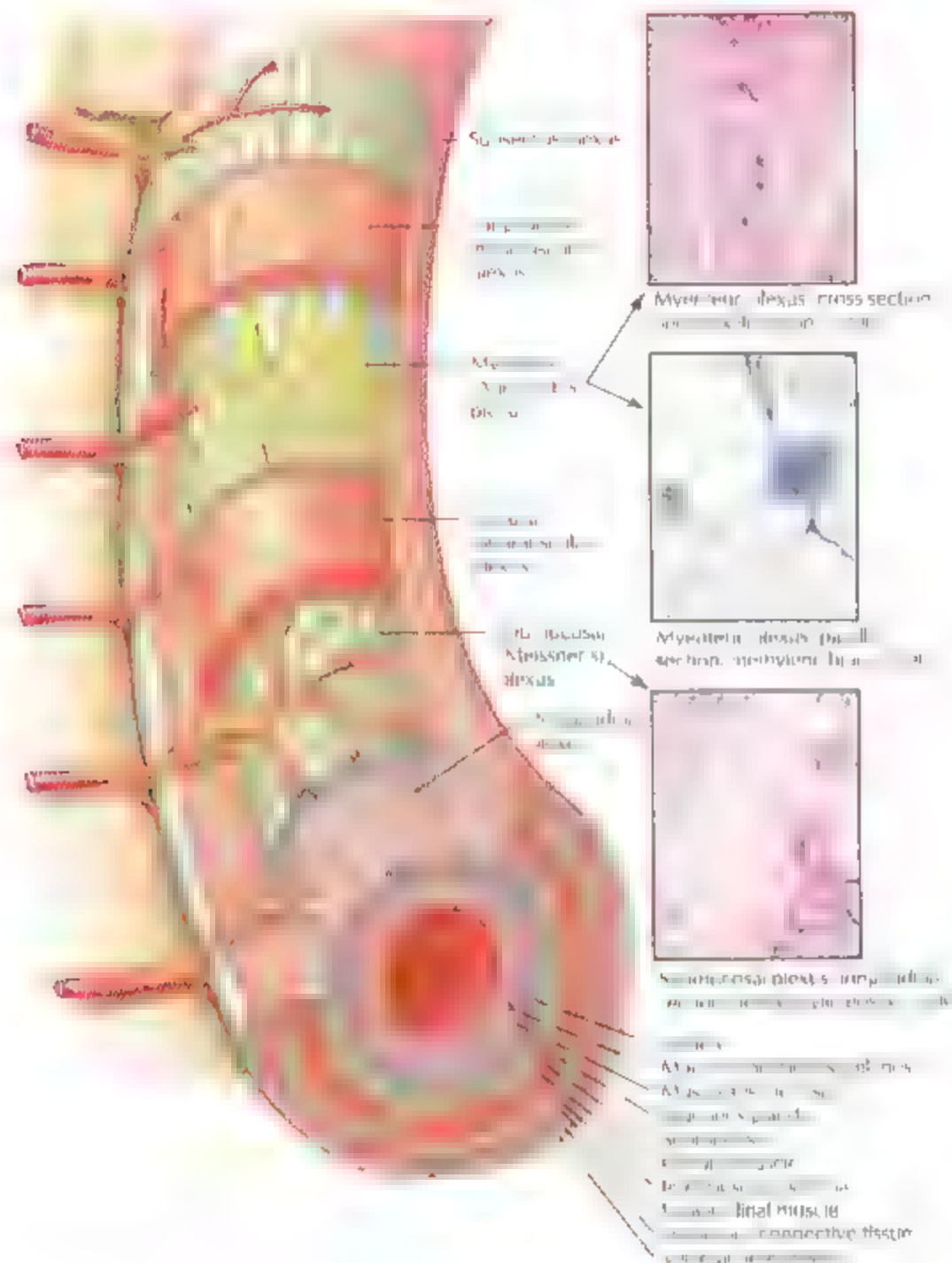


FIGURE 7.4 ENTERIC NERVOUS SYSTEM

The enteric nervous system (ENS) is a complex network of neurons and nerve fibers that control the function of the gastrointestinal tract. It is often referred to as the "second brain" of the gut. The ENS is composed of two main plexuses: the myenteric plexus (Auerbach's plexus) and the submucosal plexus (Meissner's plexus). The myenteric plexus is located between the circular and longitudinal muscle layers of the muscularis externa, while the submucosal plexus is located within the submucosa. The ENS is responsible for regulating the motility of the gut, the secretion of digestive enzymes and hormones, and the absorption of nutrients. It also plays a role in the regulation of the immune system and the response to stress. The ENS is a highly integrated system that works in concert with the central nervous system to maintain the overall health and function of the gastrointestinal tract.

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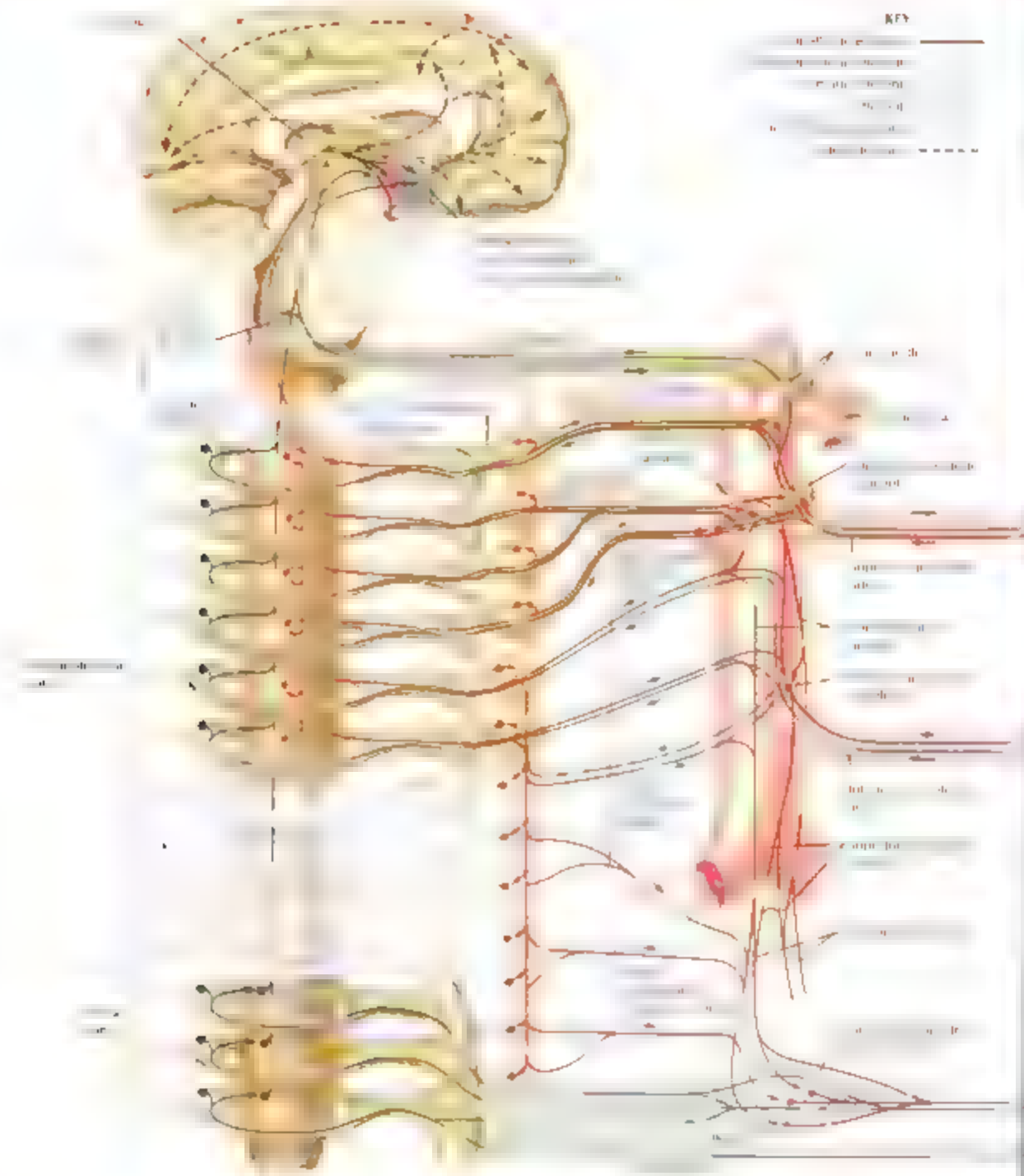


FIGURE 7.5 AUTONOMIC INNERVATION

The sympathetic nervous system (SNS) is the part of the autonomic nervous system (ANS) that is responsible for the "fight or flight" response. It is the part of the ANS that is responsible for the "fight or flight" response. The SNS is the part of the ANS that is responsible for the "fight or flight" response.

The parasympathetic nervous system (PNS) is the part of the autonomic nervous system (ANS) that is responsible for the "rest and digest" response. It is the part of the ANS that is responsible for the "rest and digest" response. The PNS is the part of the ANS that is responsible for the "rest and digest" response.



What are the effects of positive and negative reinforcement?
 - the more you practice, the more you know
 - the more you practice, the more you know
 - the more you practice, the more you know
 - the more you practice, the more you know

the more the value of ρ is close to 1, the more the hypothesis is in line with the data. In other words, the more the value of ρ is close to 1, the more the hypothesis is in line with the data.

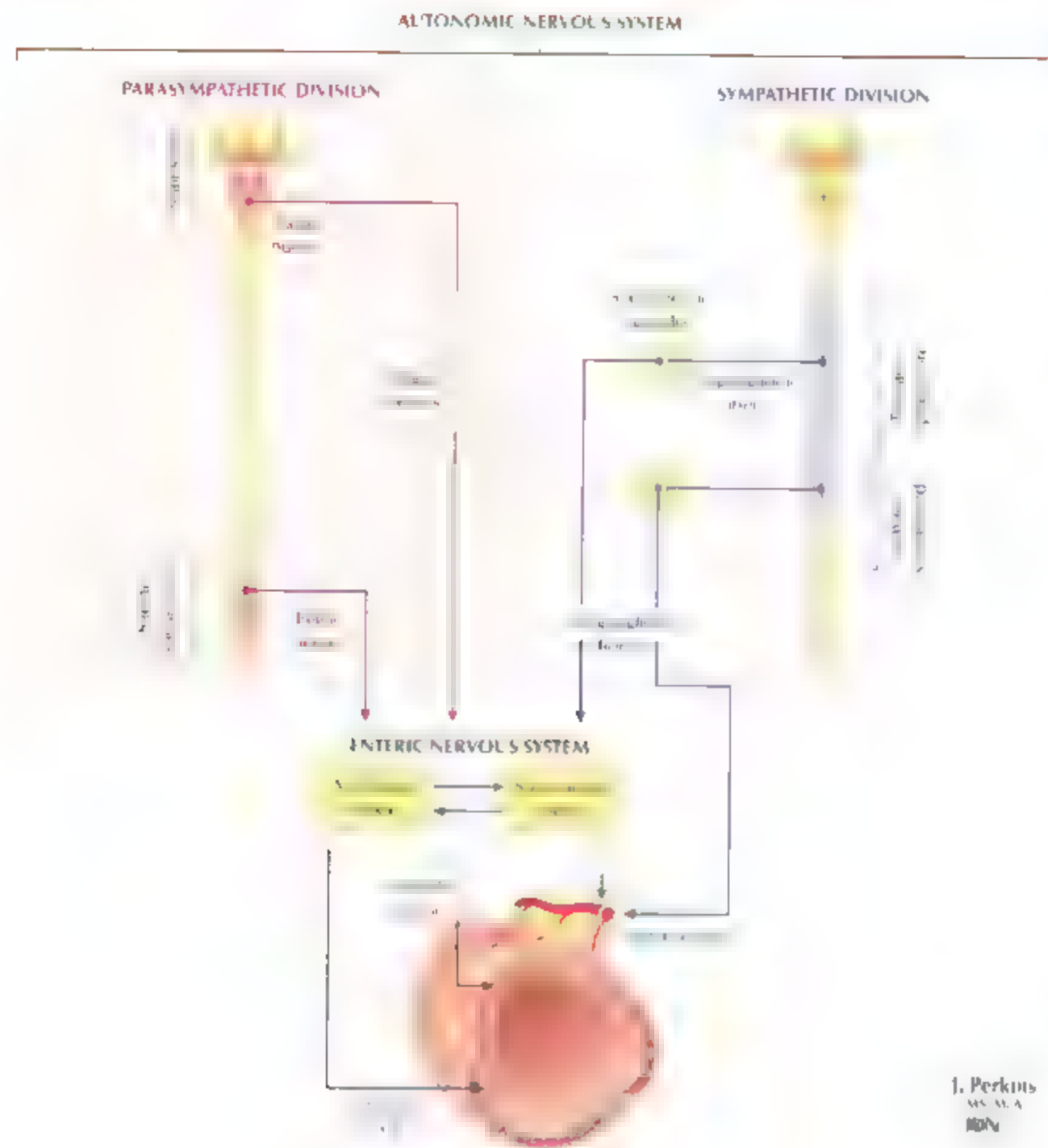


FIGURE 7.6 INTEGRATION OF AUTONOMIC AND ENTERIC NERVOUS SYSTEMS

The diagram illustrates the integration of the autonomic and enteric nervous systems. The autonomic nervous system (ANS) is divided into the parasympathetic and sympathetic divisions. The parasympathetic division (vagus nerve) and the sympathetic division (thoracic and lumbar splanchnic nerves) both innervate the enteric nervous system (ENS). The ENS is a self-contained system within the gastrointestinal tract wall, consisting of the Auerbach's plexus (myenteric plexus) and the Submucosal plexus. The ENS contains both intrinsic neurons (within the ENS) and extrinsic neurons (receiving input from the ANS). The ENS is responsible for the regulation of gastrointestinal function, including motility and secretion.

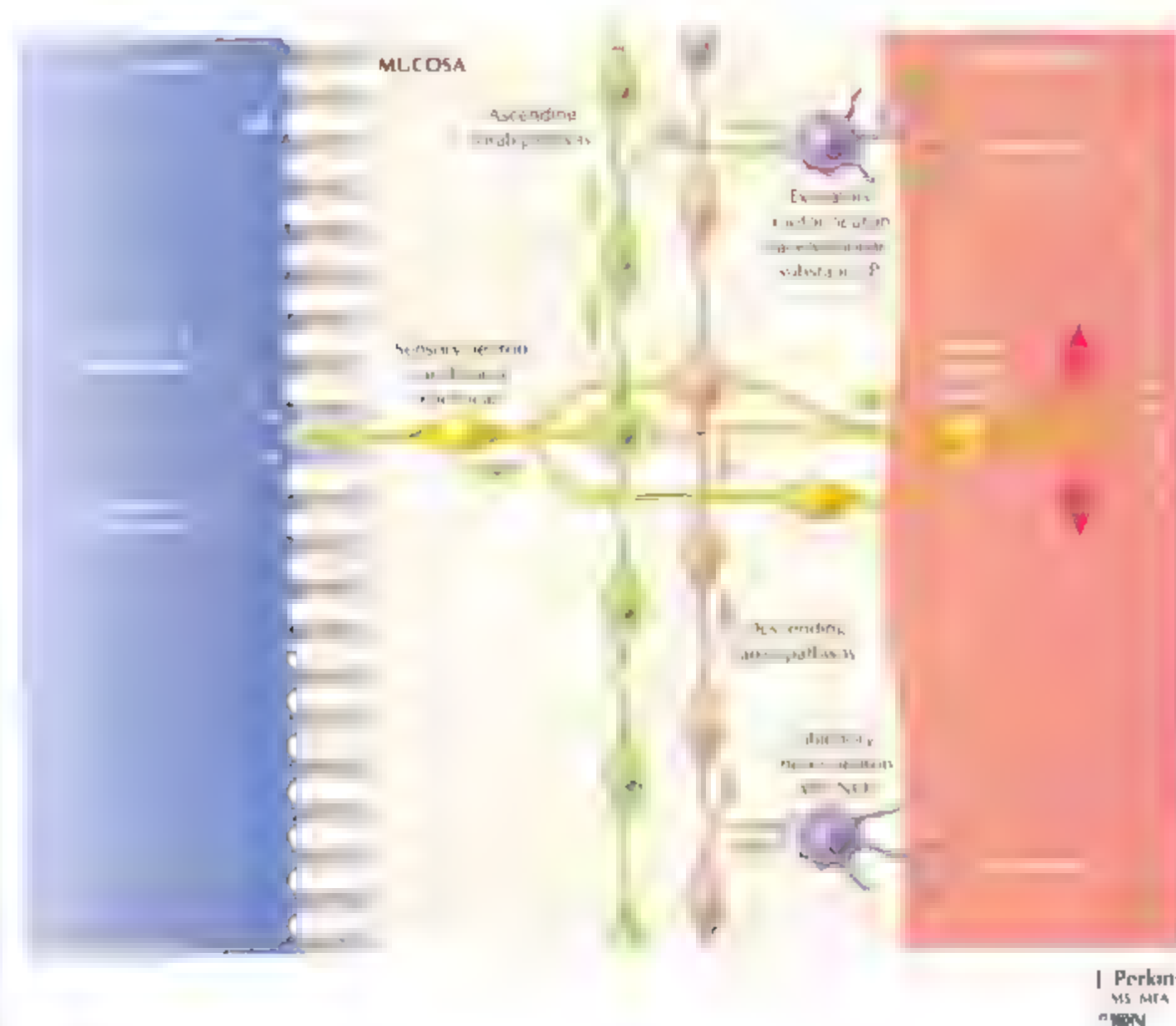
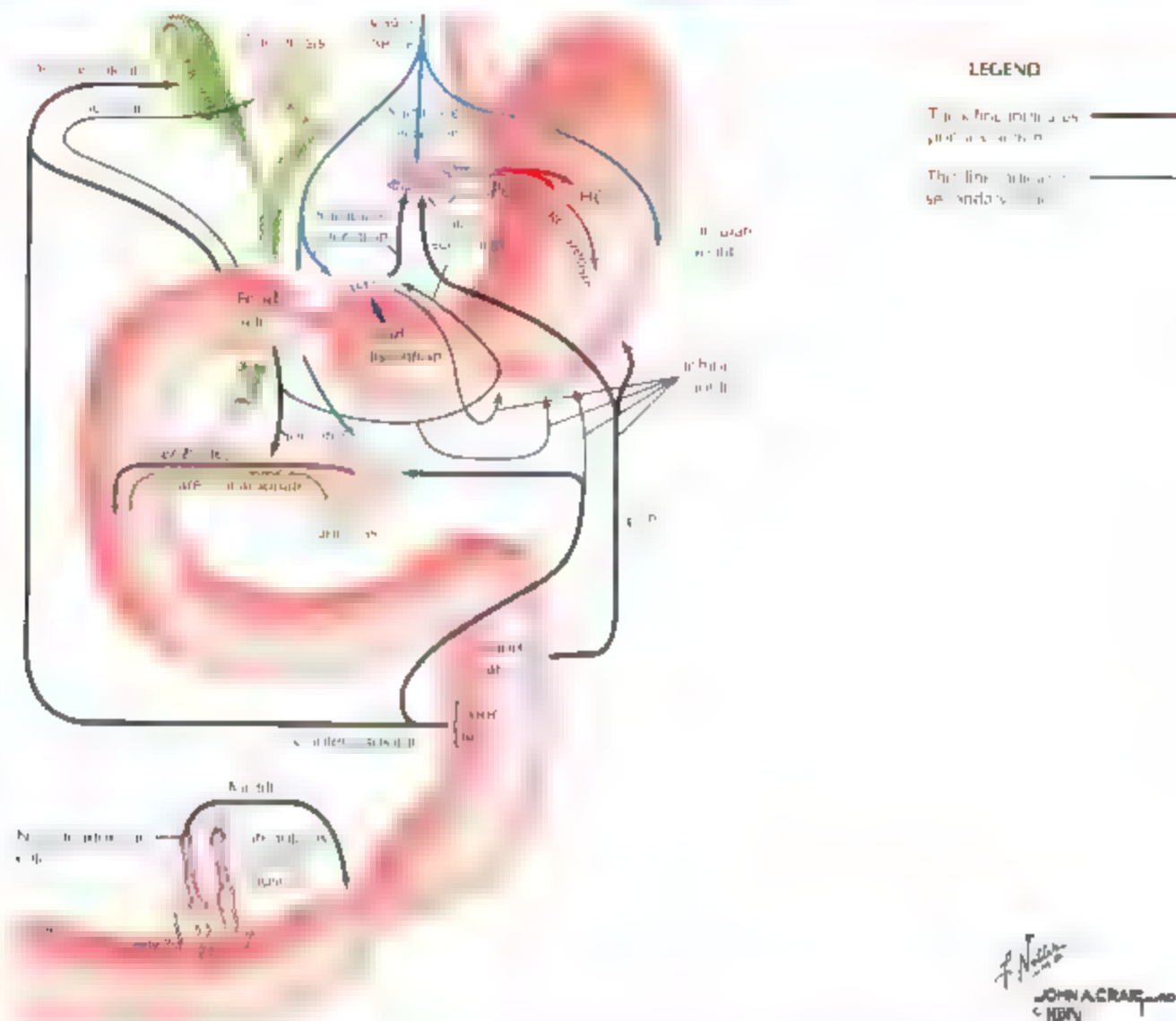


FIGURE 7.7 CONTROL OF PERISTALSIS

peristalsis is a coordinated wave of contraction that moves the contents of the gut forward. This process is controlled by the enteric nervous system (ENS), which is a network of neurons located within the gut wall. The ENS is often referred to as the "second brain" of the gut.

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Hormone	Neuroendocrine Cell Type and Location	Stimulus for Secretion	Primary Action	Other Actions
Gastrin	G cell Stomach (antrum)	Distension, low pH	Stimulate HCl secretion	Inhibit gastric emptying
Somatostatin	D cell Stomach (antrum)	High pH, distension	Inhibit gastrin secretion	Inhibit gastric emptying and stimulate bile duct secretion of bile and HCO ₃ ⁻
Secretin	S cell Duodenum	Low pH, high bile acid	Stimulate pancreatic bicarbonate secretion and HCO ₃ ⁻ secretion	Inhibit gastric emptying
Cholecystikinin (CCK)	I cell Duodenum	High pH, high bile acid	Stimulate gallbladder contraction and bile release	Inhibit gastric emptying
Motilin	M cell Duodenum, jejunum	Distension, low pH	Stimulate gastric peristalsis	Inhibit gastric emptying

FIGURE 7.8 MAJOR GI HORMONES

The following table lists the major GI hormones and their primary and secondary actions. The table also lists the location of the cells that secrete these hormones. For each hormone, the table lists the stimulus for secretion and the primary and secondary actions. The table also lists the location of the cells that secrete these hormones.

As shown in the table, the major GI hormones are secreted by the neuroendocrine cells of the GI tract. The table also lists the location of the cells that secrete these hormones. The table also lists the stimulus for secretion and the primary and secondary actions.

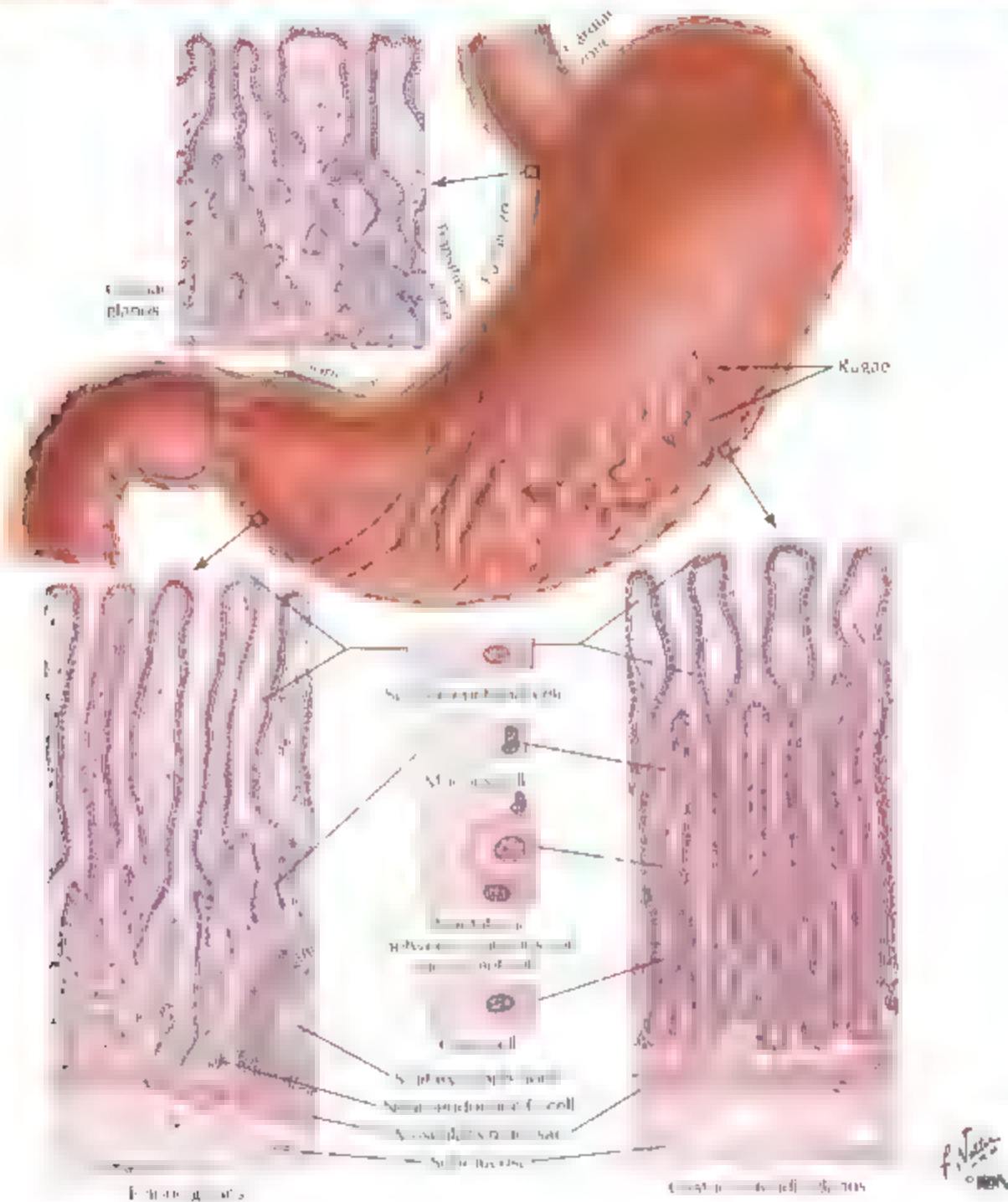


FIGURE 7.9 STRUCTURE OF THE STOMACH

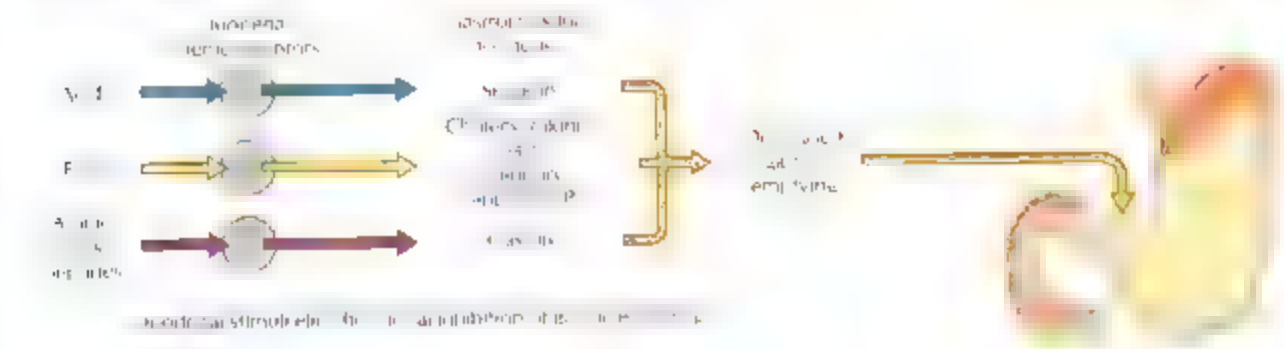
The stomach is the organ where food is digested. The epithelium of the stomach is composed of gastric pits and gastric glands. The gastric pits are the openings of the gastric glands. The gastric glands are composed of parietal cells, chief cells, and endocrine cells. The parietal cells are responsible for the secretion of hydrochloric acid (HCl) and intrinsic factor. The chief cells are responsible for the secretion of pepsinogen. The endocrine cells are responsible for the secretion of gastrin. The gastric glands are located in the mucosa of the stomach. The gastric pits are located on the surface of the mucosa. The gastric glands are located in the lamina propria. The gastric pits and glands are the sites of gastric secretion. The gastric pits are the openings of the gastric glands. The gastric glands are composed of parietal cells, chief cells, and endocrine cells. The parietal cells are responsible for the secretion of hydrochloric acid (HCl) and intrinsic factor. The chief cells are responsible for the secretion of pepsinogen. The endocrine cells are responsible for the secretion of gastrin. The gastric glands are located in the mucosa of the stomach. The gastric pits are located on the surface of the mucosa. The gastric glands are located in the lamina propria. The gastric pits and glands are the sites of gastric secretion.

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express appetite and give the sensation of satiety in the absence of the level. These hormones are long-term regulators of food intake, may have the potential to which is produced in the cells. When a person is high, the appetite is increased and the body is an in the type of food is suppressed appetite when body's not it is a depleted it in levels are very

Factors Affecting Gastric Emptying



Sequence of Gastric Motility

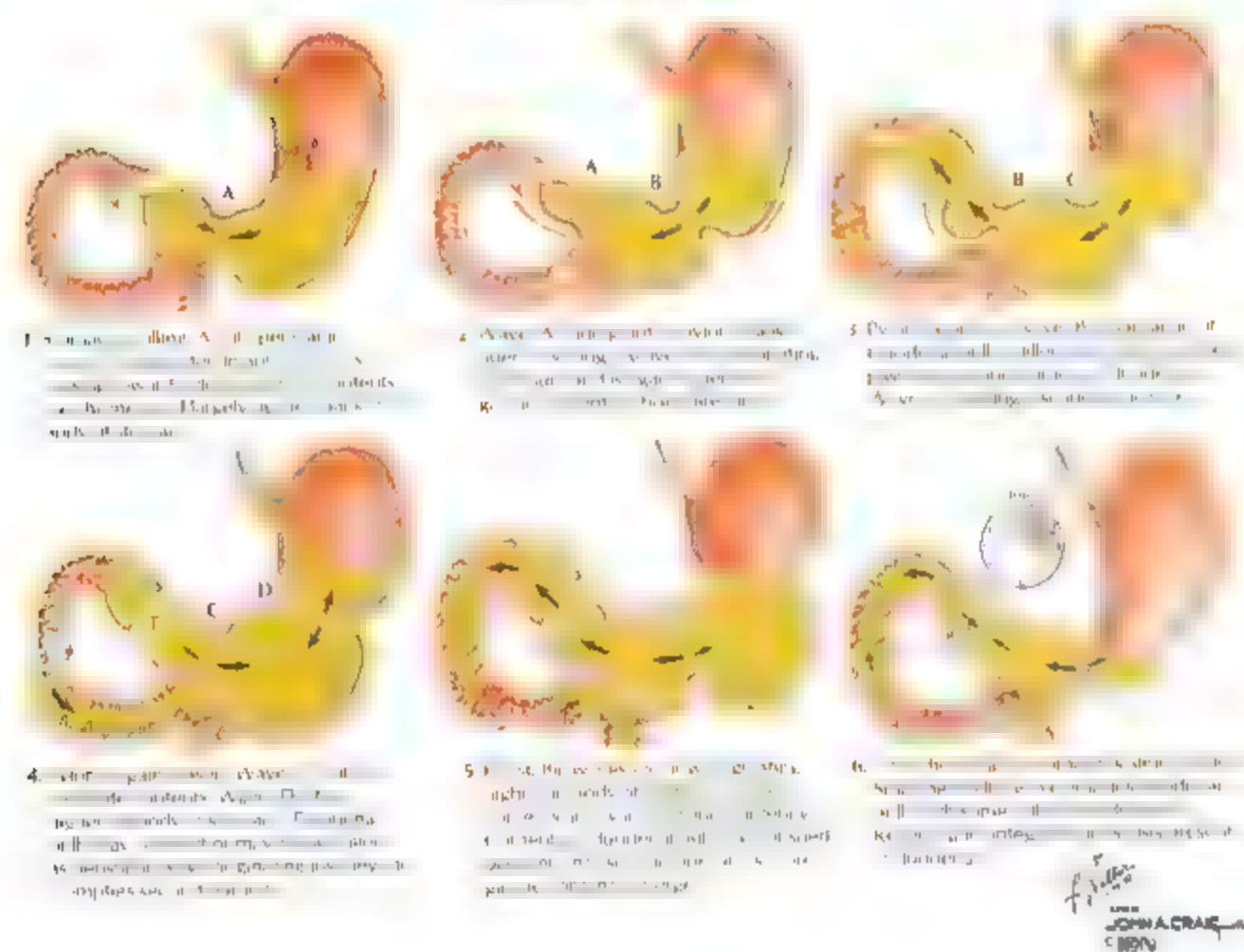


FIGURE 7.11 GASTRIC MOTILITY

The motility of the stomach is under neural and hormonal control. As the small and large intestines are under autonomic control, the stomach is also. The autonomic nervous system (ANS) controls the stomach's motility. The vagus nerve (parasympathetic) stimulates the stomach, while the sympathetic nervous system inhibits it. The enteric nervous system (ENS) also plays a role in gastric motility. The ENS is located in the wall of the gastrointestinal tract and can function independently of the brain and spinal cord. The ENS is composed of two main parts: the submucosal plexus and the myenteric plexus. The submucosal plexus is located in the submucosa and controls the movement of the intestinal wall. The myenteric plexus is located between the layers of the muscularis and controls the contraction of the smooth muscle. The ENS is often referred to as the "second brain" because it can function independently of the brain and spinal cord. The ENS is also influenced by the vagus nerve and the sympathetic nervous system. The vagus nerve stimulates the ENS, while the sympathetic nervous system inhibits it. The ENS is responsible for the peristaltic waves that move food through the gastrointestinal tract. The peristaltic waves are coordinated by the ENS and the vagus nerve. The ENS also controls the secretion of gastric juices. The gastric juices are secreted by the parietal cells in the stomach. The ENS stimulates the parietal cells to secrete gastric acid. The gastric acid is necessary for the digestion of food. The ENS also controls the relaxation of the pylorus. The pylorus is the opening between the stomach and the small intestine. The ENS relaxes the pylorus to allow food to enter the small intestine. The ENS also controls the contraction of the pylorus. The pylorus contracts to prevent food from entering the small intestine. The ENS is a complex system that plays a vital role in the digestion of food. The ENS is often referred to as the "second brain" because it can function independently of the brain and spinal cord. The ENS is also influenced by the vagus nerve and the sympathetic nervous system. The vagus nerve stimulates the ENS, while the sympathetic nervous system inhibits it. The ENS is responsible for the peristaltic waves that move food through the gastrointestinal tract. The peristaltic waves are coordinated by the ENS and the vagus nerve. The ENS also controls the secretion of gastric juices. The gastric juices are secreted by the parietal cells in the stomach. The ENS stimulates the parietal cells to secrete gastric acid. The gastric acid is necessary for the digestion of food. The ENS also controls the relaxation of the pylorus. The pylorus is the opening between the stomach and the small intestine. The ENS relaxes the pylorus to allow food to enter the small intestine. The ENS also controls the contraction of the pylorus. The pylorus contracts to prevent food from entering the small intestine. The ENS is a complex system that plays a vital role in the digestion of food.

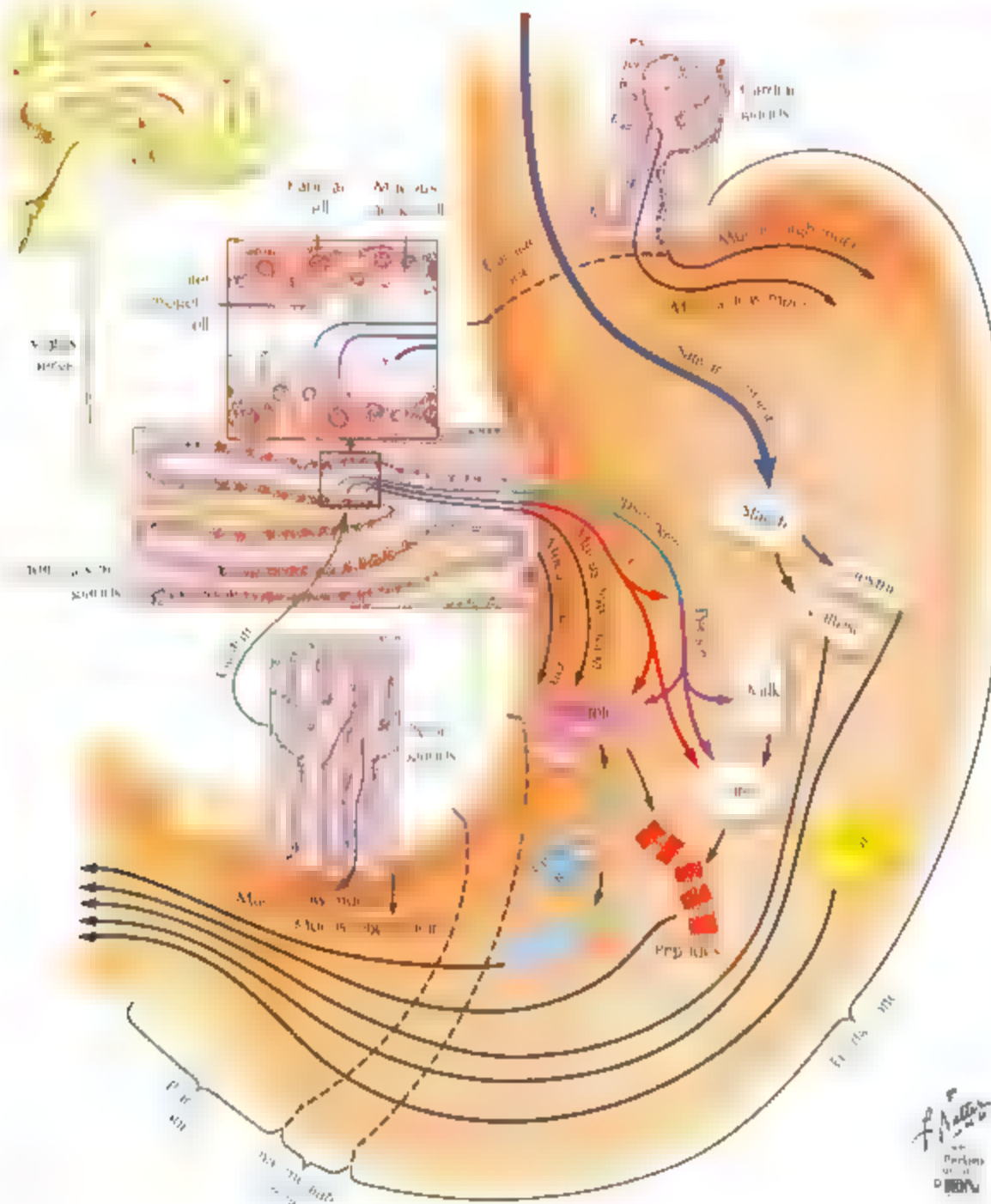


FIGURE 7.12 GASTRIC DIGESTIVE FUNCTION

The stomach serves as the site of gastric digestion. In addition to the enzymatic digestion of proteins through the action of pepsin and HCl, it also serves as a site for the absorption of water and electrolytes. The pH is 1.5 in the stomach and 7.5 in the duodenum.

The mouth and stomach are regulated by the presence of food and the rate of gastric secretion. The gastric cells also secrete intrinsic factor, which is necessary for the absorption of vitamin B₁₂. The stomach also serves as a site for the absorption of water and electrolytes.

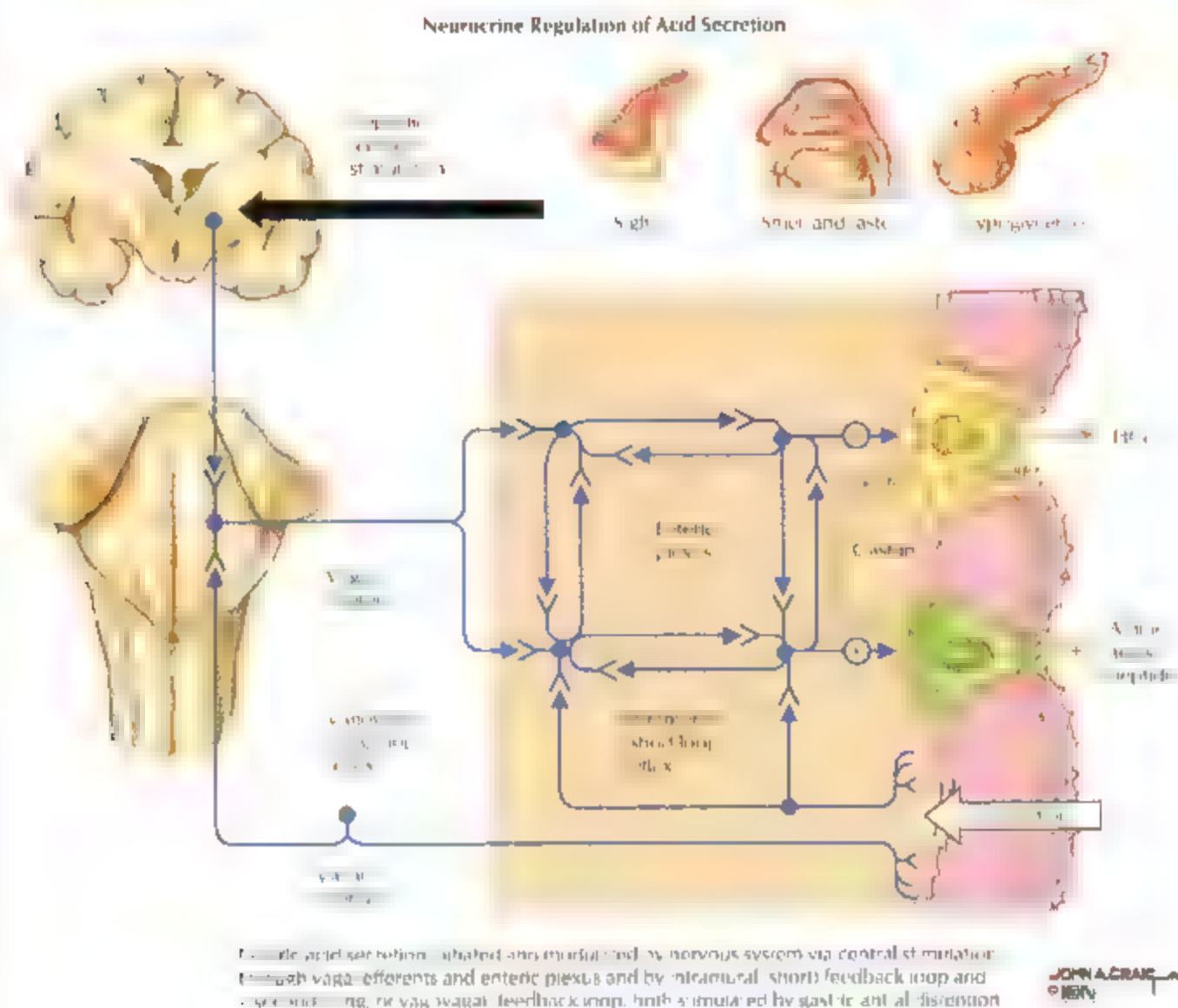
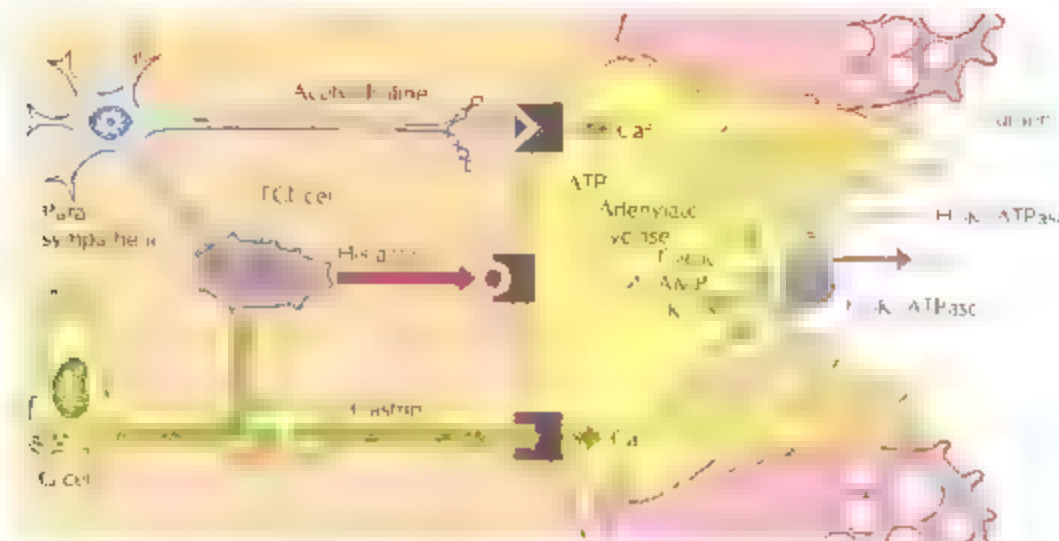


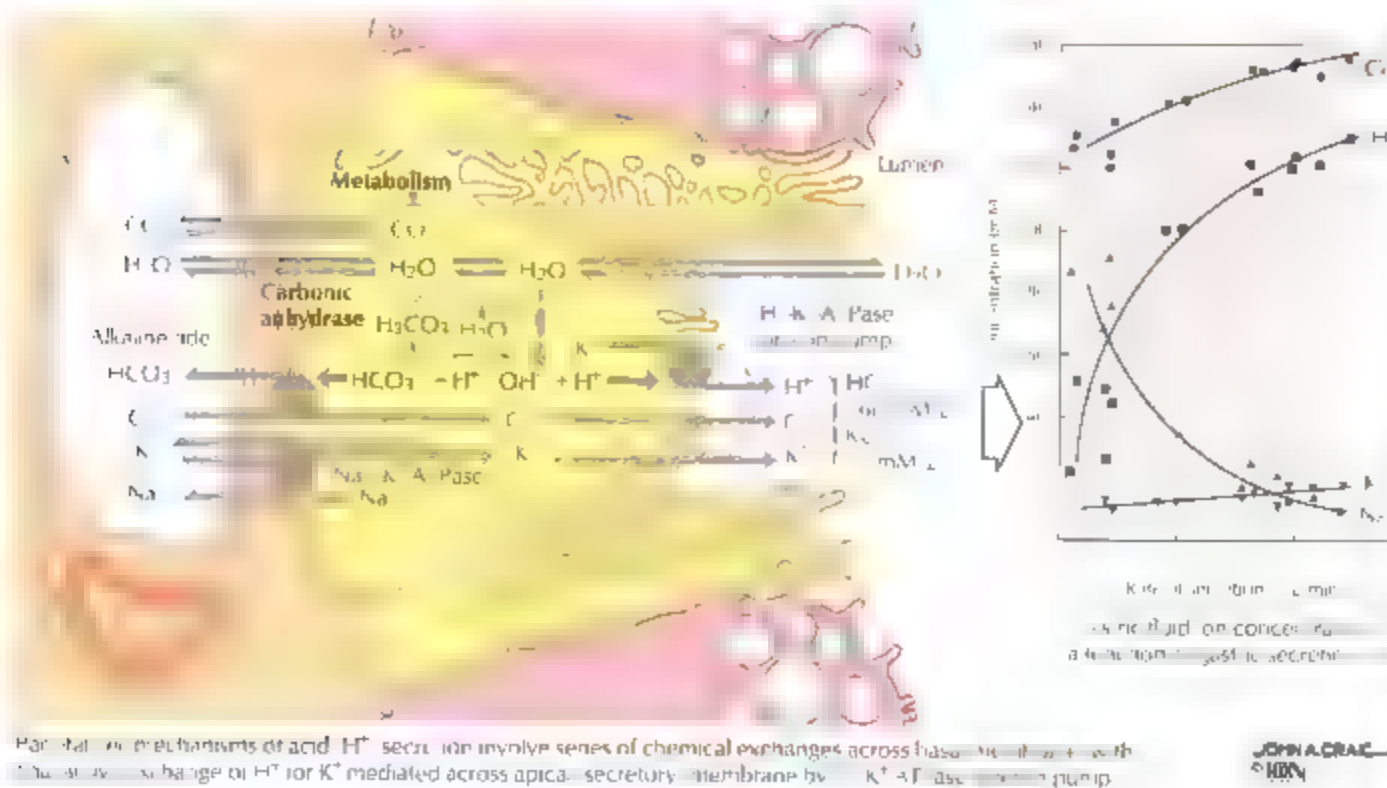
FIGURE 7.13 VAGAL CONTROL OF GASTRIC SECRETION

Acid secretion in response to sight, smell, and taste is known as cephalic phase of gastric secretion. This is stimulated by the nervous system. In the cephalic phase, the vagus nerve is stimulated by the brain, which then stimulates the parietal cells to secrete gastric acid. This is known as the cephalic phase of gastric secretion.

The enteric nervous system (ENS) is a network of neurons located in the gastrointestinal tract. It is responsible for the regulation of gastric secretion. The ENS is divided into the vagus nerve and the enteric plexus. The vagus nerve is responsible for the regulation of gastric secretion, while the enteric plexus is responsible for the regulation of gastric secretion. The ENS is a complex system that regulates the function of the gastrointestinal tract.



Secretion of gastric acid (H^+) by parietal cell mediated by neurocrine, paracrine, and endocrine mechanisms. Modulation of secretion by these mechanisms affects intracellular Ca^{2+} levels.



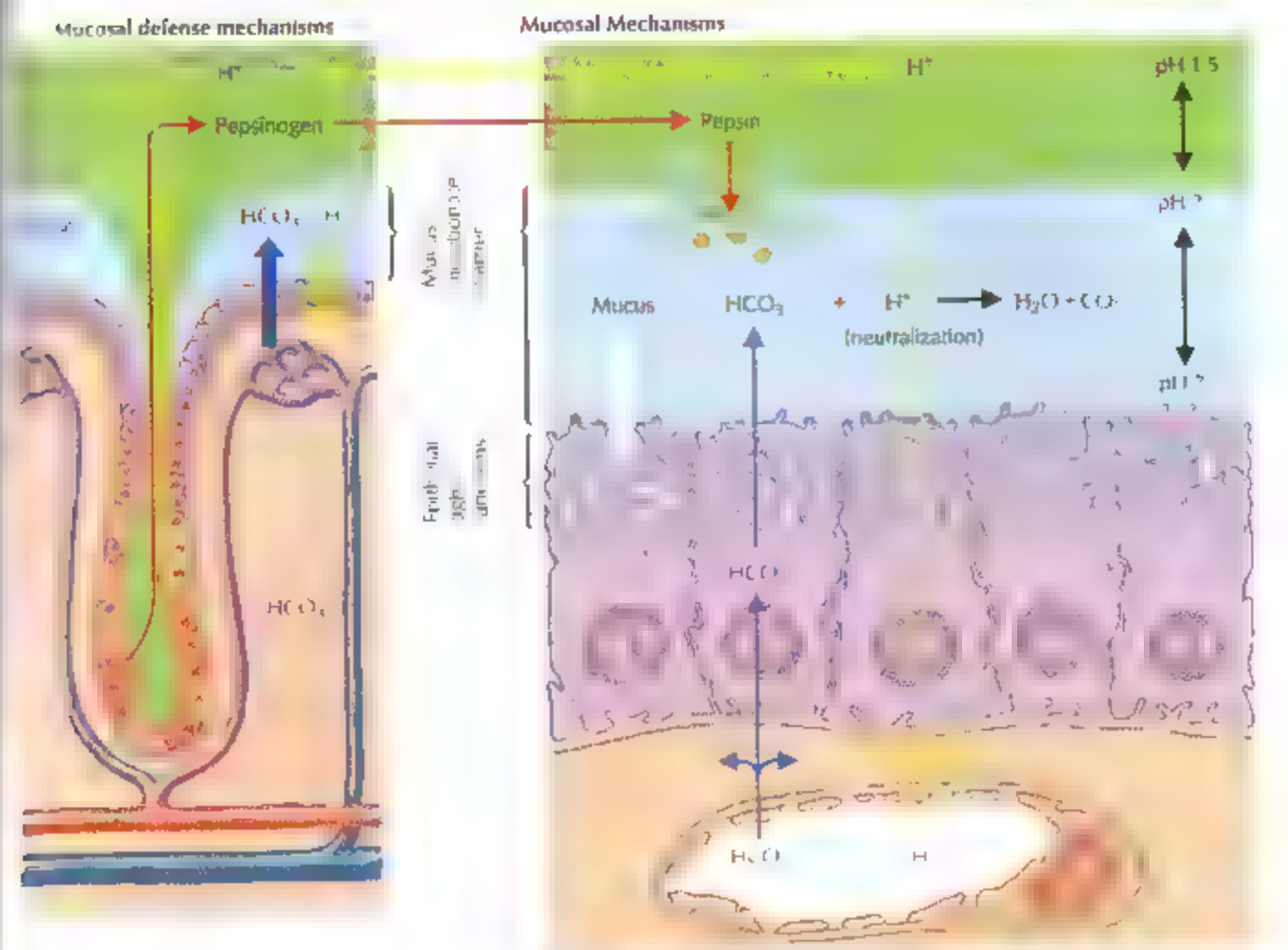
Parietal cell mechanisms of acid (H^+) secretion involve series of chemical exchanges across basolateral membrane with Na^+ and K^+ exchange of H^+ for K^+ mediated across apical secretory membrane by H^+ K^+ ATPase pump.

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FIGURE 7.14 REGULATION OF PARIENTAL CELL FUNCTION

Parietal cells secrete H^+ via an H^+ K^+ ATPase. H^+ pump. Ca^{2+} and carbonic dehydratase with the H^+ and Cl^- produces HCl in the lumen. (1) The H^+ is secreted into the lumen. The parietal cells are regulated by neurocrine, paracrine, and endocrine mechanisms. The paracrine and endocrine mechanisms involve histamine and gastrin, which bind to receptors on the parietal cell, activating a G-protein and PKA, which then activates the H^+ K^+ ATPase pump.

The parietal cell is the only cell in the stomach that secretes HCl . The parietal cell is regulated by neurocrine, paracrine, and endocrine mechanisms. The paracrine and endocrine mechanisms involve histamine and gastrin, which bind to receptors on the parietal cell, activating a G-protein and PKA, which then activates the H^+ K^+ ATPase pump.



Gastric mucosa and submucosa protected from chemical injury by mucus-bicarbonate surface barrier that neutralizes gastric H^+ and by epithelial "tight junctions" that prevent H^+ access to subepithelial tissue

JOHN A. CRAIG and
CRAIG

FIGURE 7.15 MUCOSAL DEFENSE MECHANISMS

The high-mucin-containing mucus produced by the surface epithelial cells protects the stomach from abrasion and provides a relatively alkaline environment for the epithelial cells. This mucus layer trans-

bicarbonate and remains relatively stable, providing a pH of 7 above the surface epithelium, compared to a pH of 1 in the gastric lumen.

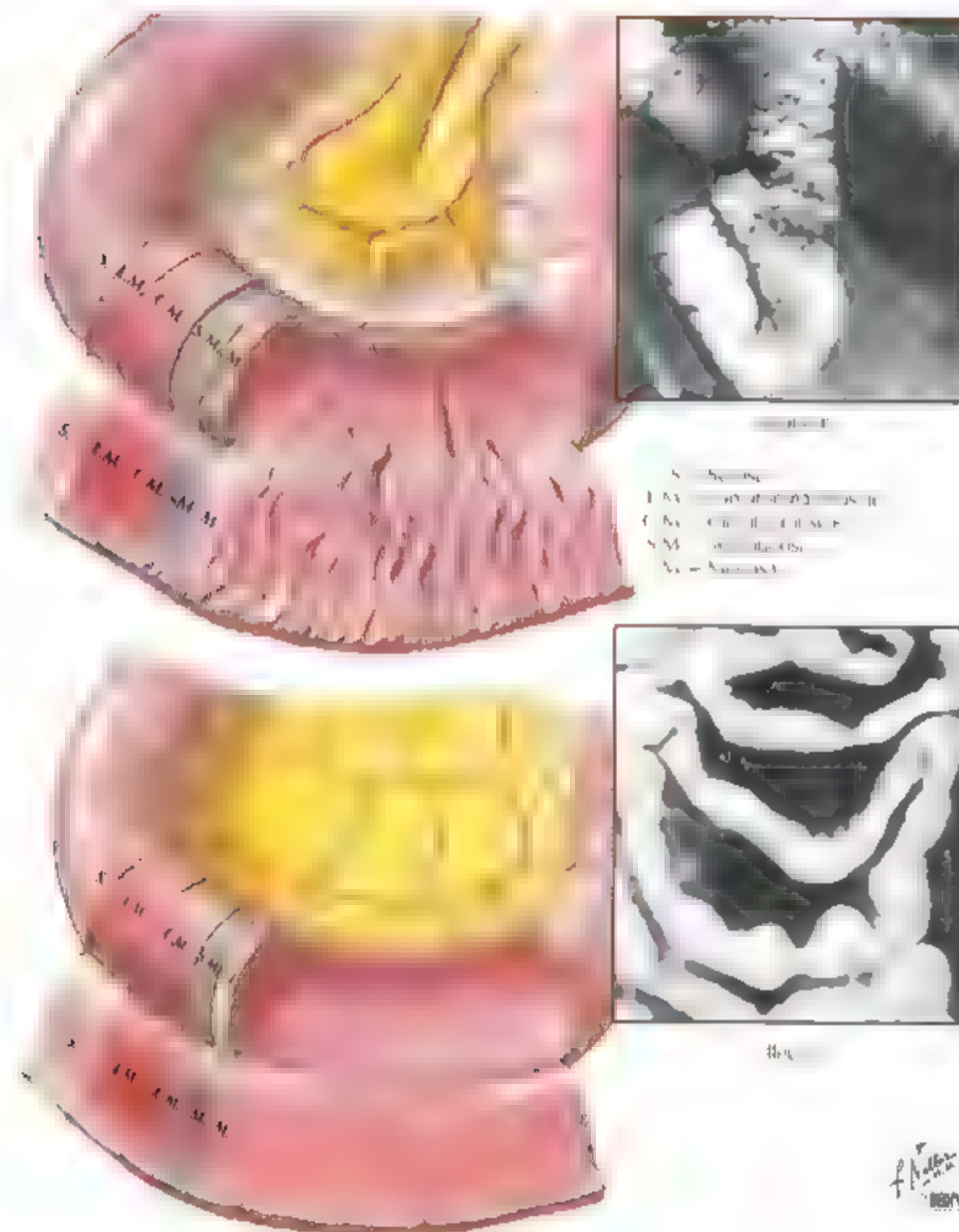


FIGURE 7.16 SMALL INTESTINE STRUCTURE

The jejunum, ileum, and cecum are parts of the small intestine. The jejunum is the middle section, about 5 m long, while the ileum and cecum are about 1 m long. The jejunum is the part of the small intestine that is responsible for the absorption of nutrients. The ileum is the part of the small intestine that is responsible for the absorption of bile salts and vitamin B₁₂. The cecum is the part of the large intestine that is responsible for the absorption of water and electrolytes.

Small intestine has many villi (finger-like projections) on its inner surface. These villi increase the surface area of the small intestine, which allows for more efficient absorption of nutrients. The villi are covered by a single layer of epithelial cells, which are responsible for the absorption of nutrients. The villi are also covered by a layer of mucus, which helps to protect the villi from damage.

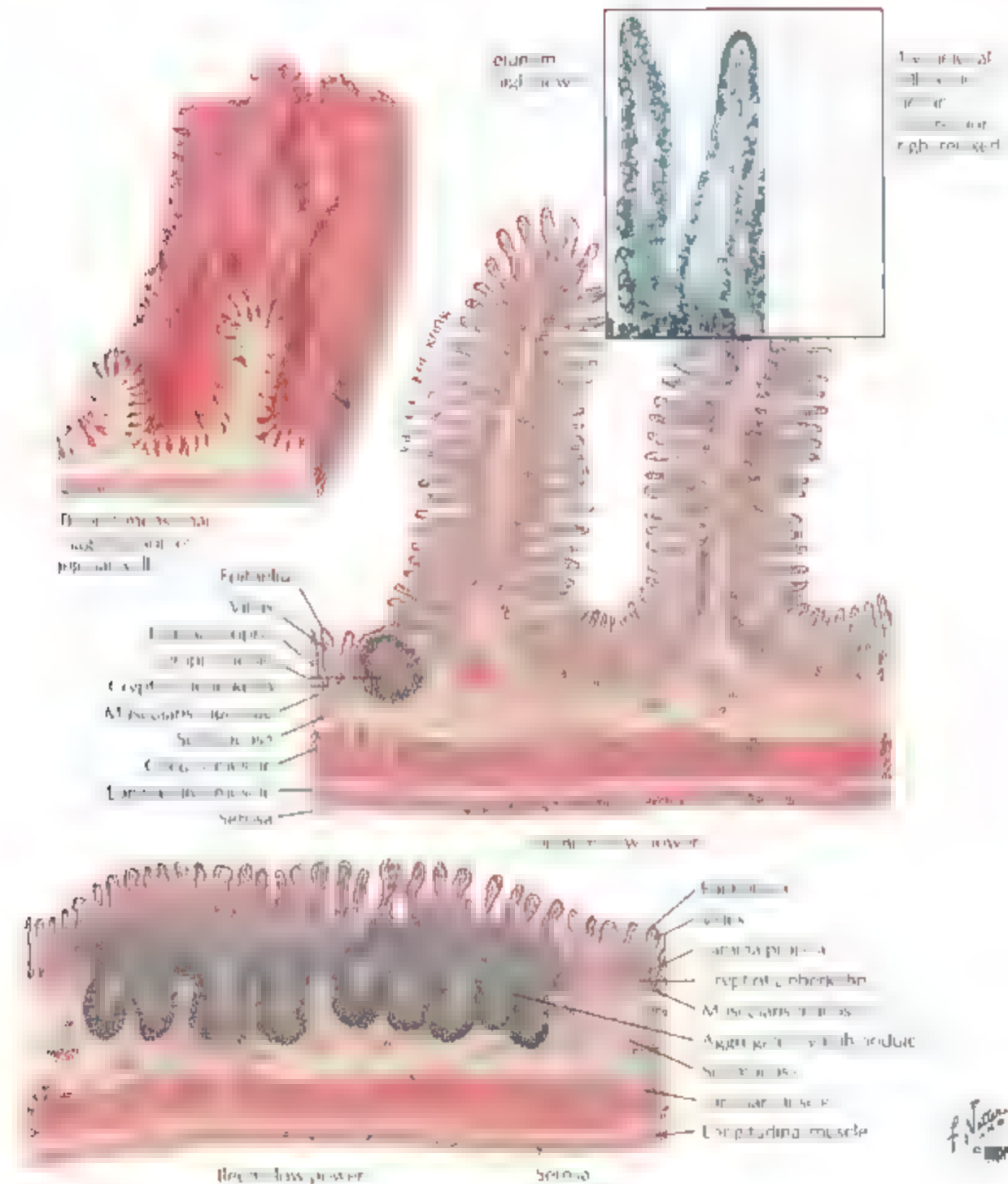


FIGURE 7.17 SMALL INTESTINE MICROSCOPIC STRUCTURE

The small intestine has a large surface area for secretion and absorption. The surface area is increased by the presence of circular folds, villi, and crypts. Because the mucosa provides a large surface area for absorption, the crypts represent a site for the absorption of nutrients. The villi represent a site for the absorption of nutrients.

The villi are formed by the intestinal proper and submucosa. The villi are covered by a single layer of columnar epithelium. The crypts are formed by the intestinal proper and submucosa. The crypts are covered by a single layer of columnar epithelium. The villi and crypts are covered by a single layer of columnar epithelium.

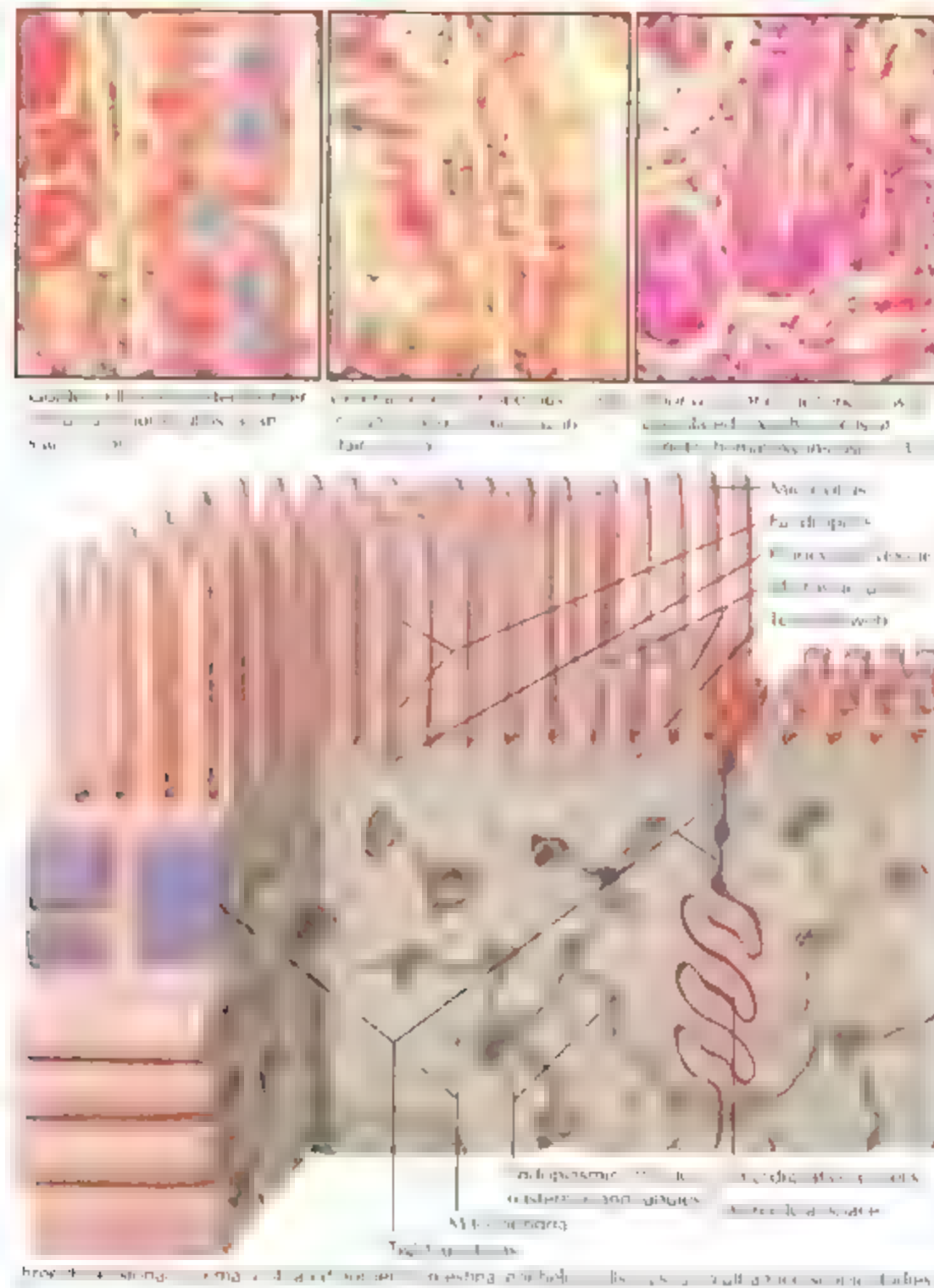


FIGURE 7.18 EPITHELIUM OF THE SMALL INTESTINE

The villi are lined with a single layer of columnar epithelial cells. The apical membrane of the enterocytes contains numerous microvilli. The lateral membranes are involved in the exchange of nutrients and the secretion of enzymes. The basal part of the enterocytes, among the enterocytes are zonula occludens, which are

microvilli. The zonula occludens are located at the base of the villi and are the site where the actively dividing cells are found. The new cells move up the villi over the course of a few days and are shed over the lumen. The villi are also the site of the absorption of nutrients and the secretion of enzymes.

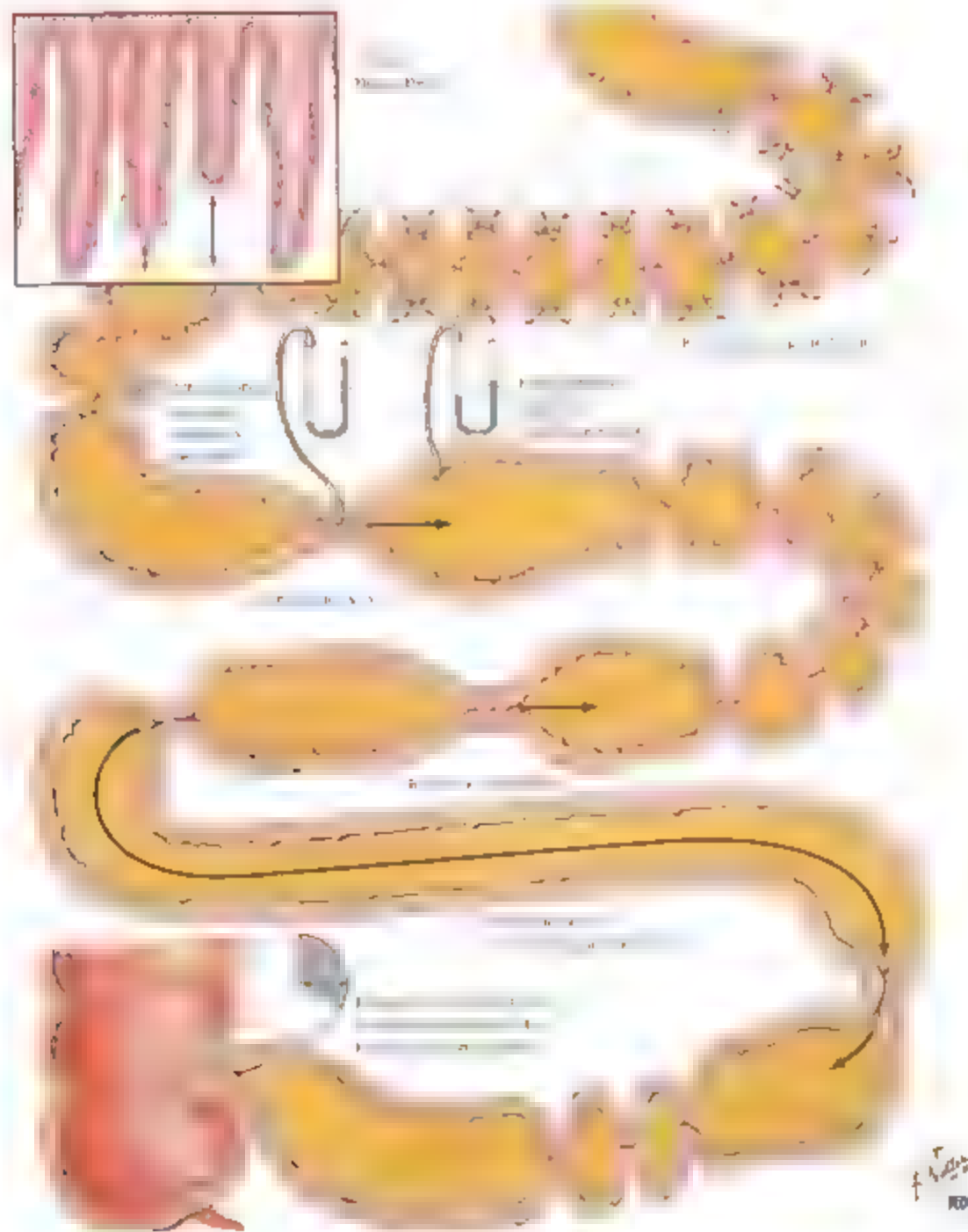


FIGURE 7.19 MOTILITY OF THE SMALL INTESTINE

The small intestine is the longest part of the gastrointestinal tract, measuring about 6 meters (20 feet) in length. It is divided into three parts: the duodenum, jejunum, and ileum. The duodenum is the first part, followed by the jejunum, and then the ileum, which ends at the cecum. The small intestine is responsible for the majority of the digestion and absorption of nutrients from the food we eat.

The motility of the small intestine is controlled by the enteric nervous system, which is a part of the autonomic nervous system. The enteric nervous system consists of a network of neurons located in the wall of the gastrointestinal tract. These neurons are responsible for coordinating the contractions of the smooth muscle layers of the gastrointestinal tract, which move food through the system.

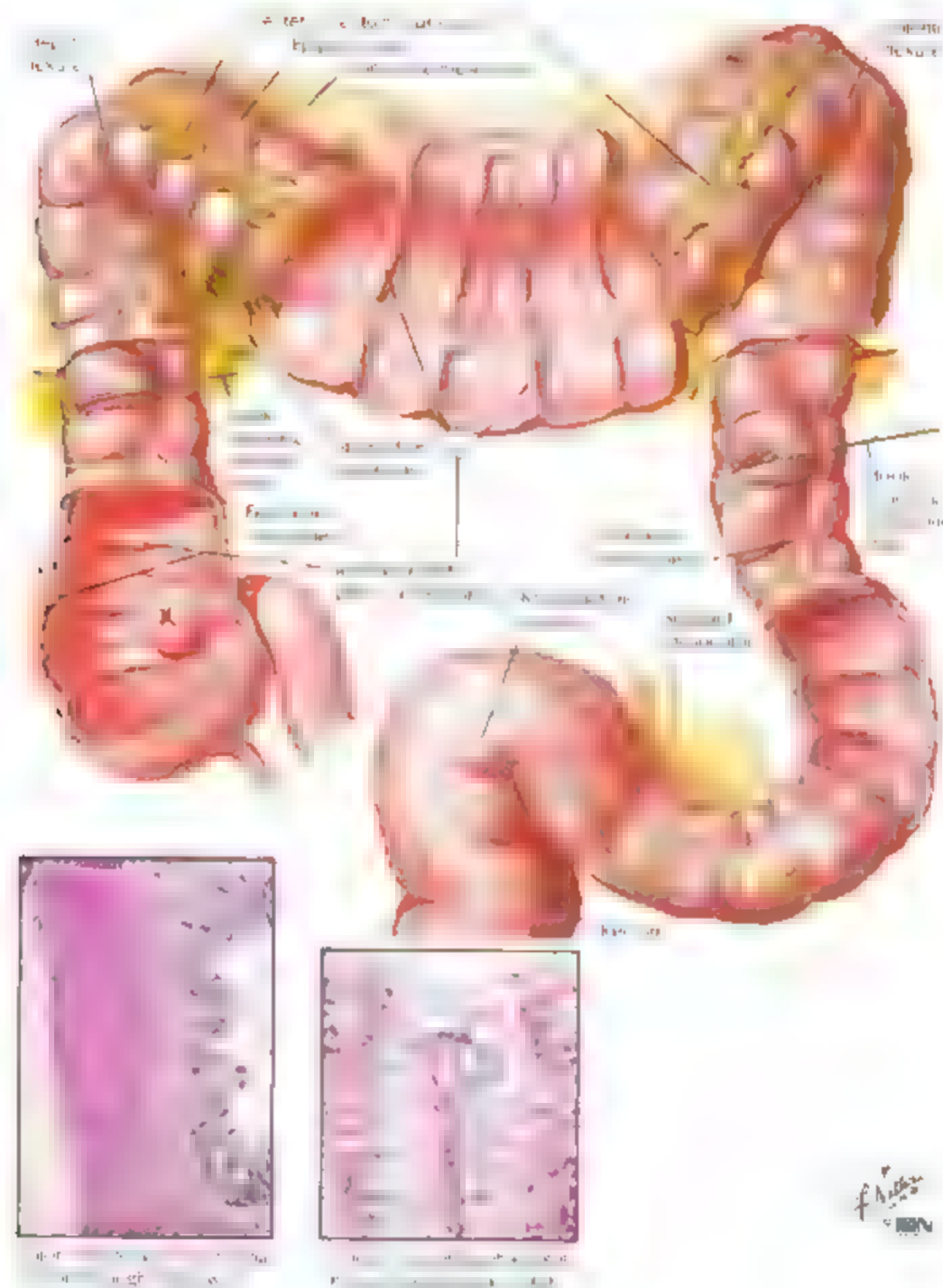


FIGURE 7.20 LARGE INTESTINE STRUCTURE

The large intestine is the terminal part of the digestive tract. It is responsible for the absorption of water and electrolytes, and the formation of feces. The large intestine is divided into several parts: the cecum, ascending colon, transverse colon, descending colon, sigmoid colon, and rectum. The appendix is a small, finger-like projection from the cecum.

The large intestine is a muscular organ that contracts and relaxes to move contents along. It is also responsible for the production of certain vitamins, such as vitamin K and biotin. The large intestine is a part of the digestive tract that is often overlooked, but it plays a crucial role in maintaining overall health.





FIGURE 7.22 COLONIC MOTILITY

As the peristaltic wave moves down the colon, it causes the haustra to contract and the contents to move forward. The haustra are the sac-like pouches that form the large intestine. The haustra are the sac-like pouches that form the large intestine. The haustra are the sac-like pouches that form the large intestine.

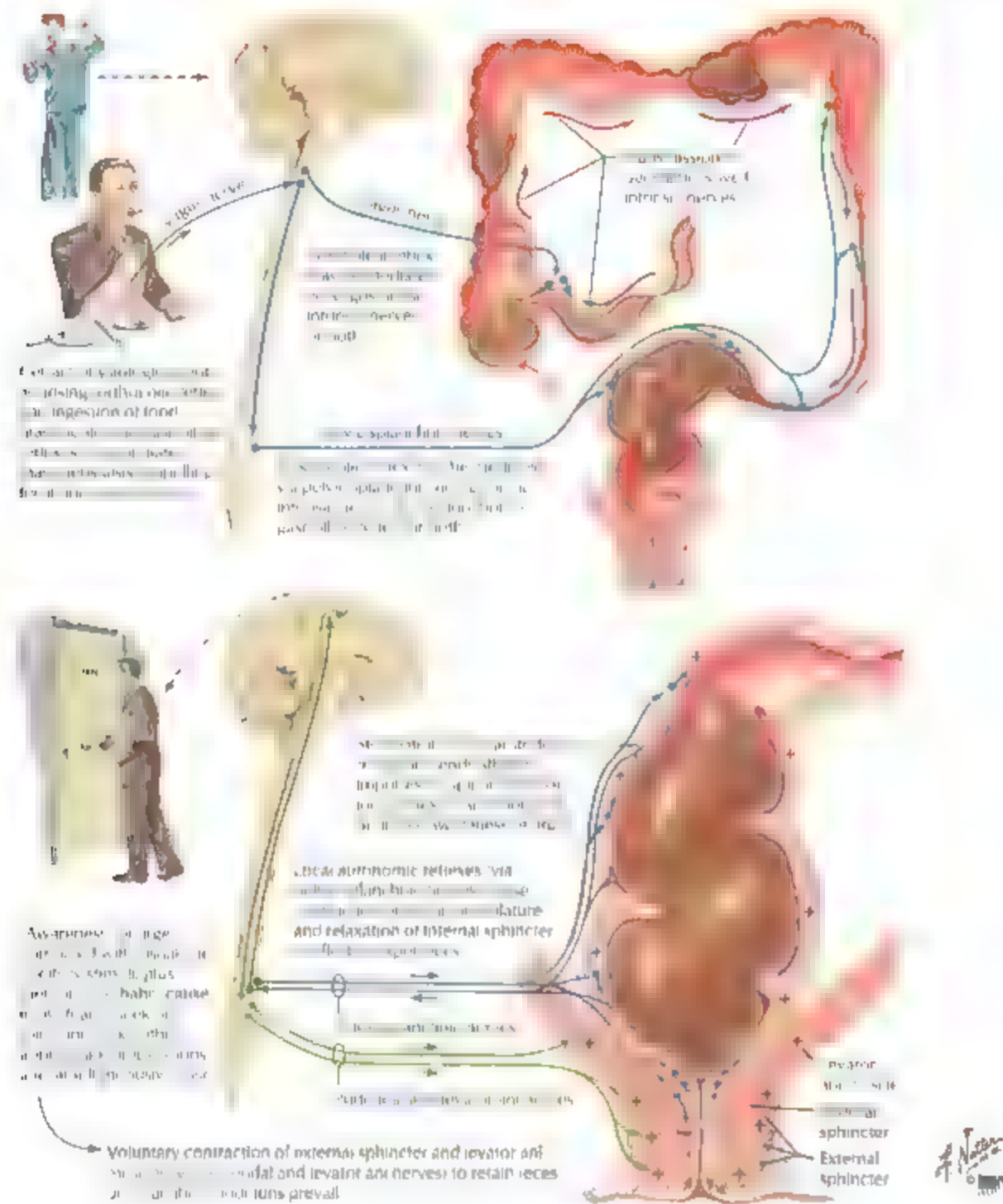


FIGURE 7.23 DEFECATION

Defecation involves heaving the rectosigmoid colon reflexly to relax the internal anal sphincter and voluntary contraction of the external anal sphincter and levator ani muscles to retain feces.

Reflex defecation involves relaxation of the internal anal sphincter and voluntary relaxation of the external anal sphincter and levator ani muscles to defecate.

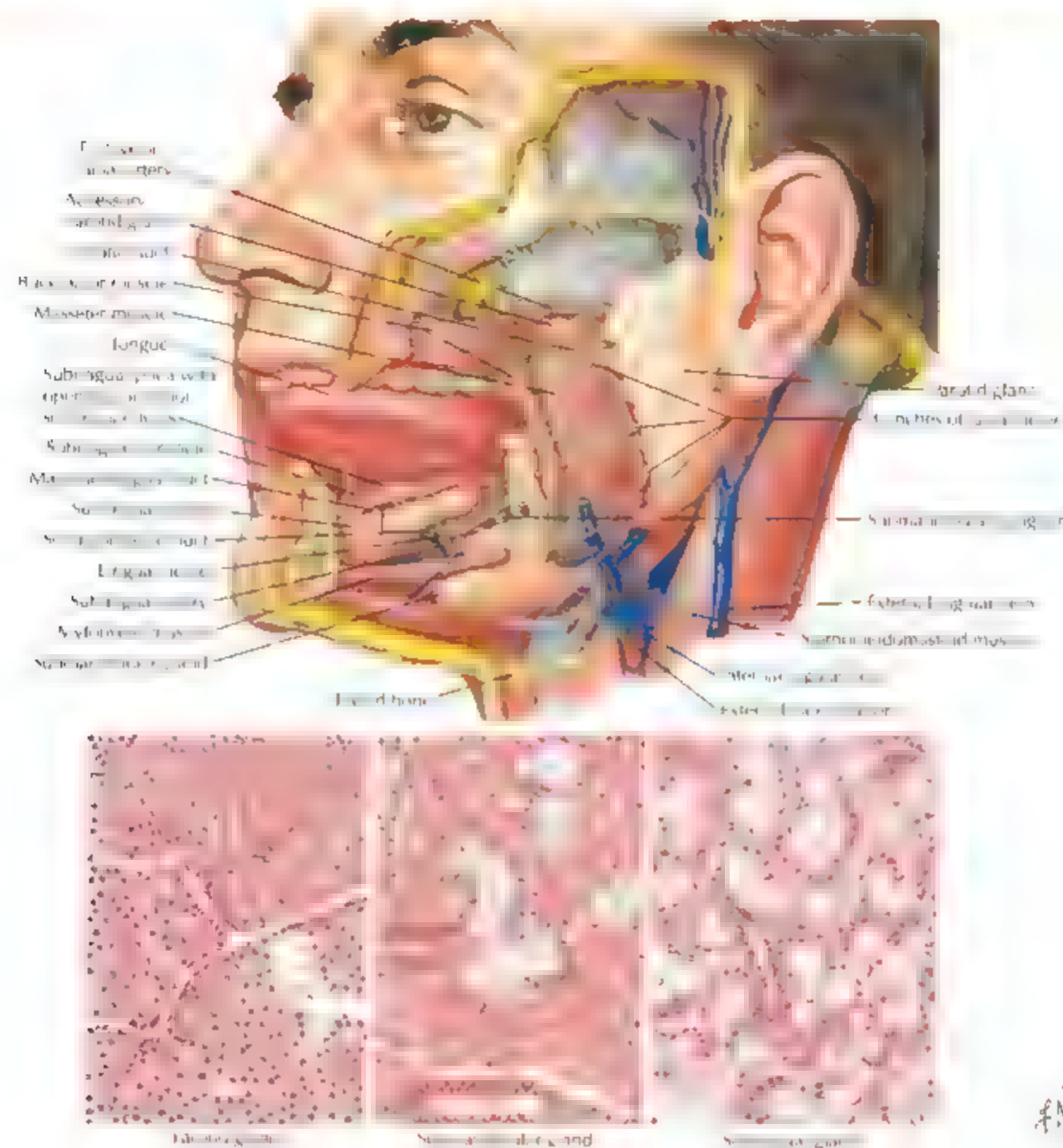


FIGURE 7-24 SALIVARY GLAND STRUCTURE

The salivary glands secrete several enzymes, including amylase, which is responsible for the digestion of starch and the breakdown of proteins. The salivary glands also secrete mucin, which is responsible for the lubrication of the mouth. The salivary glands also secrete lysozyme, which is responsible for the destruction of bacteria. The salivary glands also secrete IgA, which is responsible for the immune response. The salivary glands also secrete epidermal growth factor, which is responsible for the growth of the skin. The salivary glands also secrete histamine, which is responsible for the allergic response. The salivary glands also secrete serotonin, which is responsible for the regulation of the digestive system. The salivary glands also secrete melatonin, which is responsible for the regulation of the circadian rhythm. The salivary glands also secrete melatonin, which is responsible for the regulation of the circadian rhythm.

the salivary glands, where the salivary glands are responsible for the production of saliva. The salivary glands are composed of serous and mucous glands. The serous glands are responsible for the production of serous saliva, which is composed of water, electrolytes, and enzymes. The mucous glands are responsible for the production of mucous saliva, which is composed of water, electrolytes, and mucus. The salivary glands are also responsible for the production of saliva, which is composed of water, electrolytes, and enzymes. The salivary glands are also responsible for the production of saliva, which is composed of water, electrolytes, and enzymes.



The salivary gland is order in human cavity. The gland secretes a highly viscous and alkaline aqueous fluid. It has the accessory digestive system as there are no teeth in it and its secretion is not directly secreted by the mouth. It is an important component of the

As a consequence, we argue that if there is a large salivary gland, it is not the gland, but the gland's morphology, which is the important factor to have. An important point is that the salivary gland of the mouth is highly branched and has a high branching ratio and a reduction

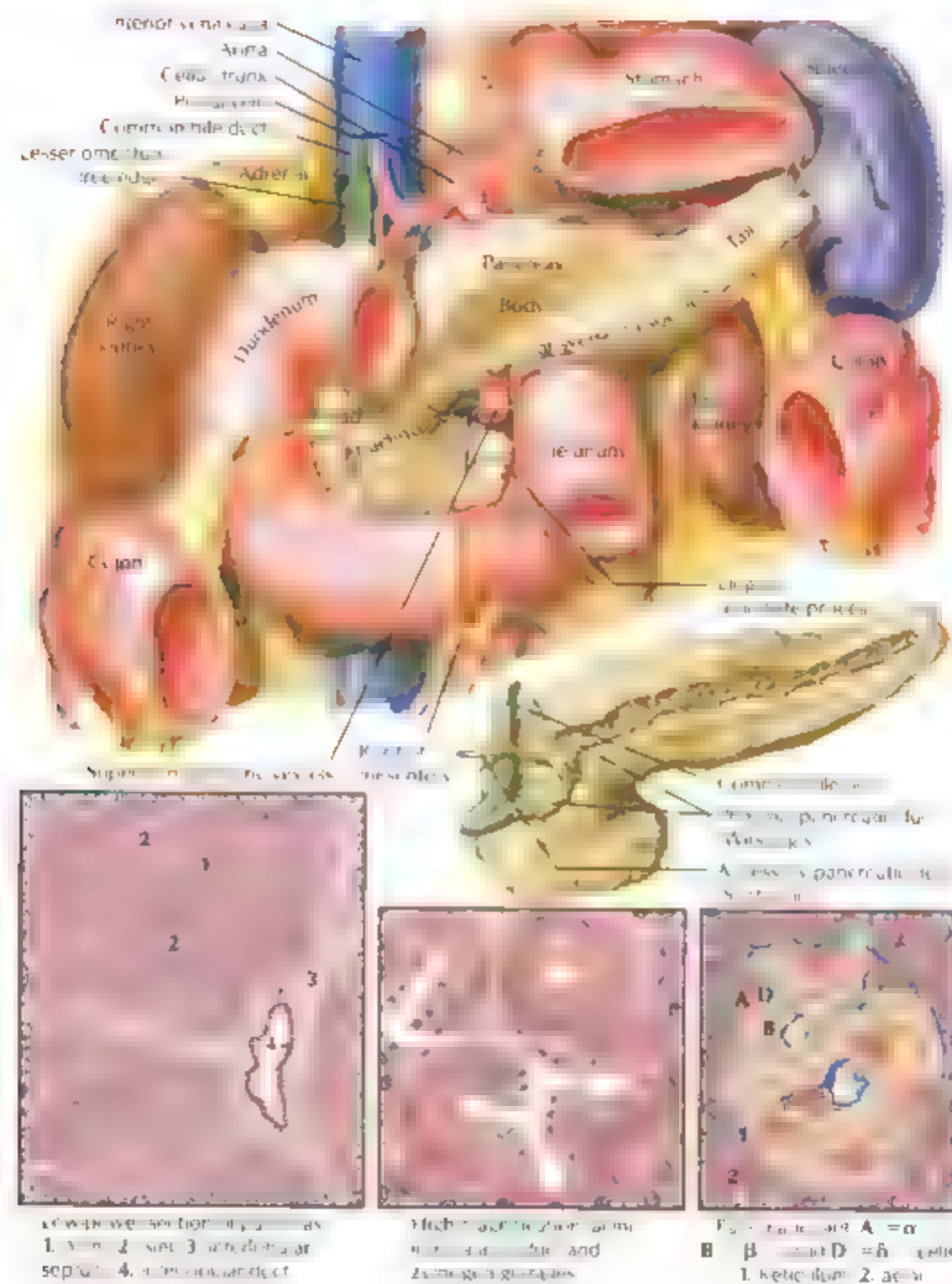


FIGURE 7.26 PANCREAS STRUCTURE

The pancreas has exocrine and endocrine components. The acinar cells of the exocrine pancreas secrete a number of enzymes that are necessary for digestion: protein, lipase, and amylase. The ductal cells secrete a fluid with a high HCO_3^- content. In the HCO_3^- secretions, bicarbonate neutralizes the acid entering the duodenum from the stomach. The

endocrine pancreas consists of islets of Langerhans. Within these islets, the α cells are located in the periphery of the islet and secrete glucagon; the β cells are located centrally within the islet and secrete insulin; and the δ cells are dispersed throughout the islet and secrete somatostatin.

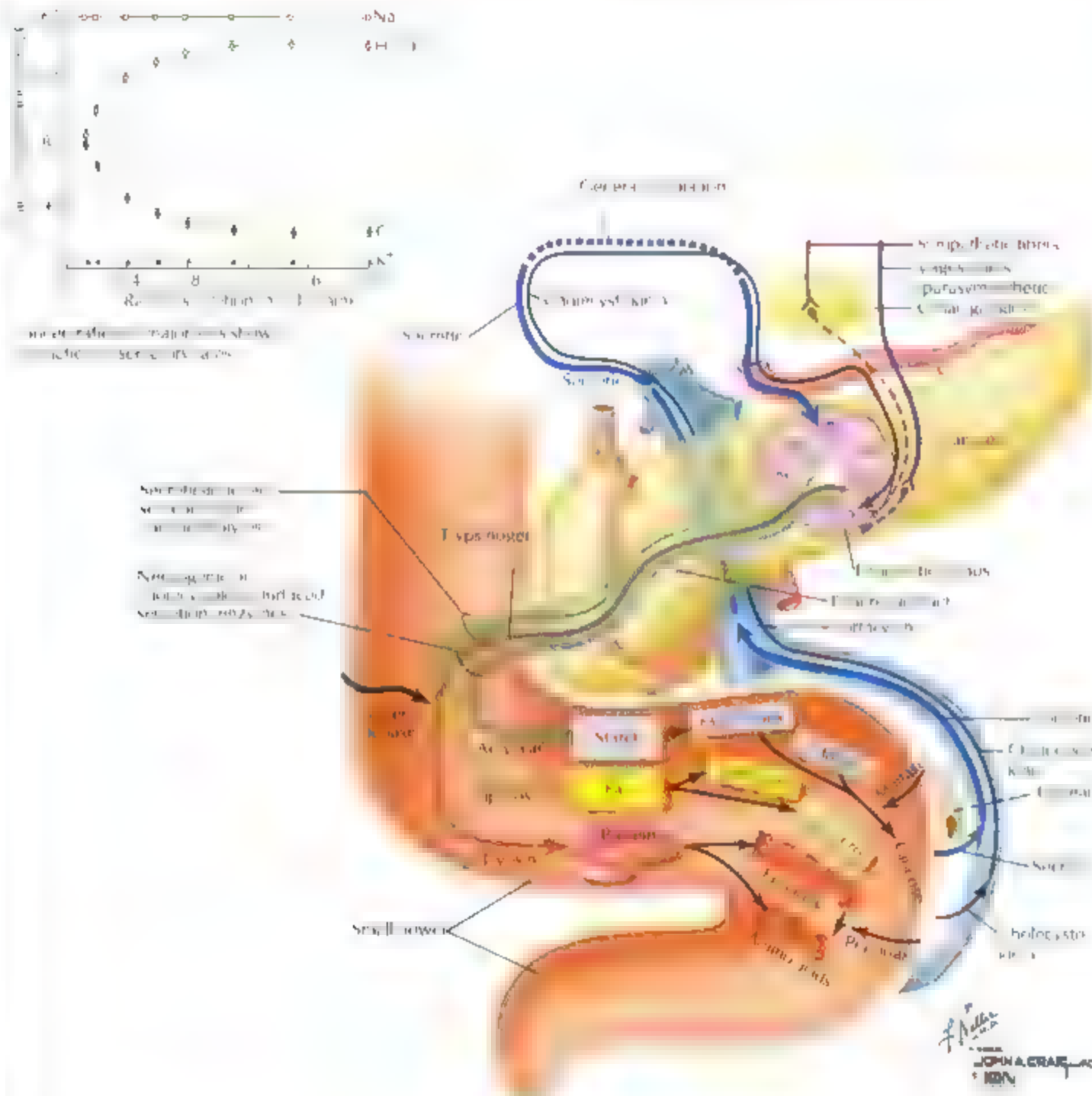


FIGURE 7.27 PANCREAS SECRETION

The pancreas is a gland that secretes both endocrine and exocrine products. The endocrine products are secreted by the islets of Langerhans, which are composed of several types of cells, including α cells (secrete glucagon), β cells (secrete insulin), δ cells (secrete somatostatin), and F cells (secrete pancreatic polypeptide). The exocrine products are secreted by the acinar cells of the pancreas, which secrete a variety of enzymes, including amylase, lipase, and trypsin.

The pancreas is also regulated by the autonomic nervous system. The parasympathetic system, via the vagus nerve, stimulates the secretion of pancreatic enzymes. The sympathetic system, via the splanchnic nerves, inhibits the secretion of pancreatic enzymes. Additionally, the pancreas is regulated by several hormones, including gastrin, secretin, cholecystikinin, and somatostatin.

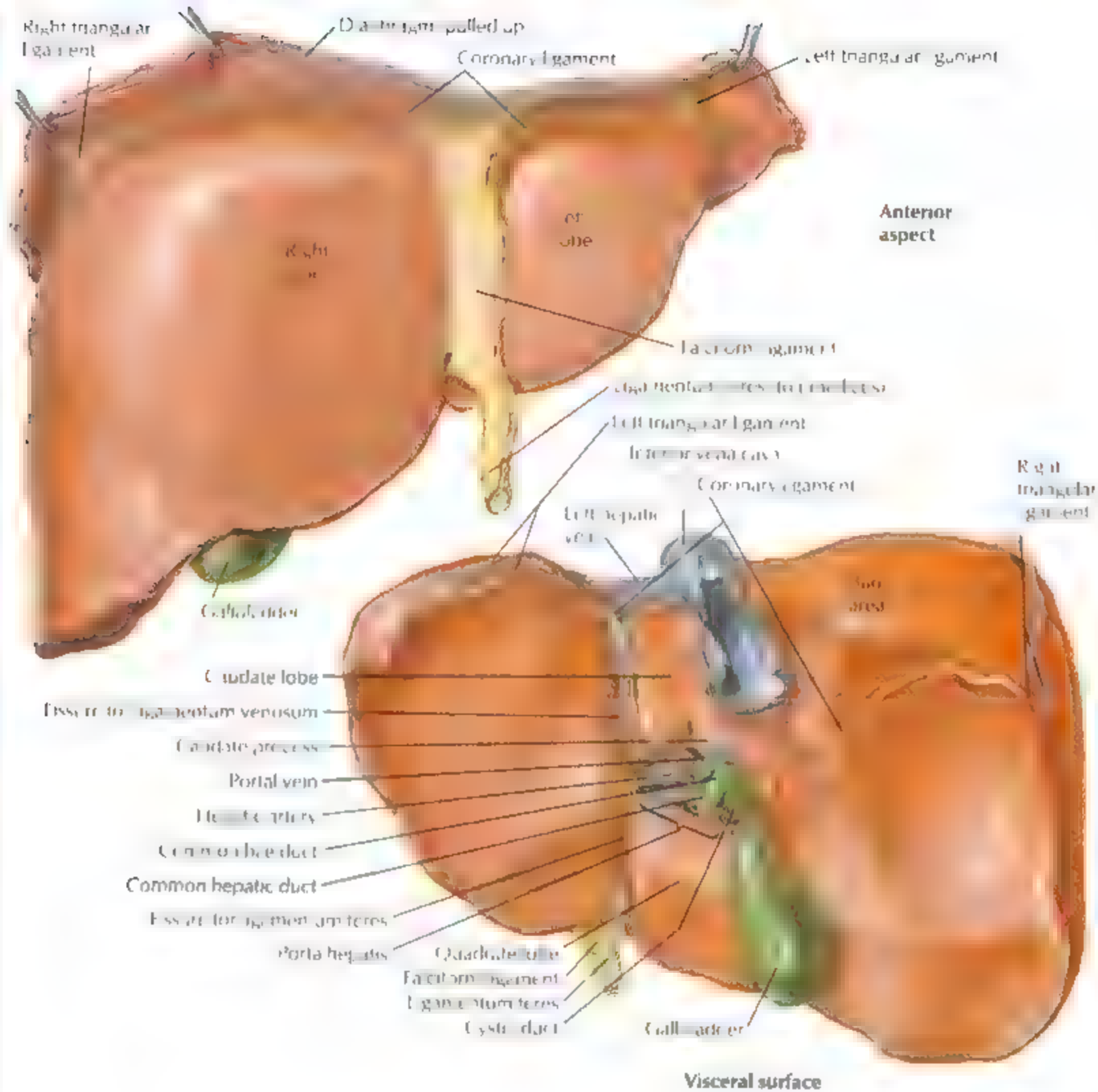


FIGURE 7.28 LIVER STRUCTURE

The liver is the largest gland in the body and consists of four anatomical lobes (right, left, quadrate and caudate). Various ligaments attach the liver to the overlying diaphragm (coronary ligaments) and anterior abdominal wall (falciform ligament). Functionally, the liver has

two lobes, right and left, and each lobe receives arterial blood from the hepatic artery and portal venous blood from the abdominal gut tract. Each lobe also possesses its own venous and biliary drainage.

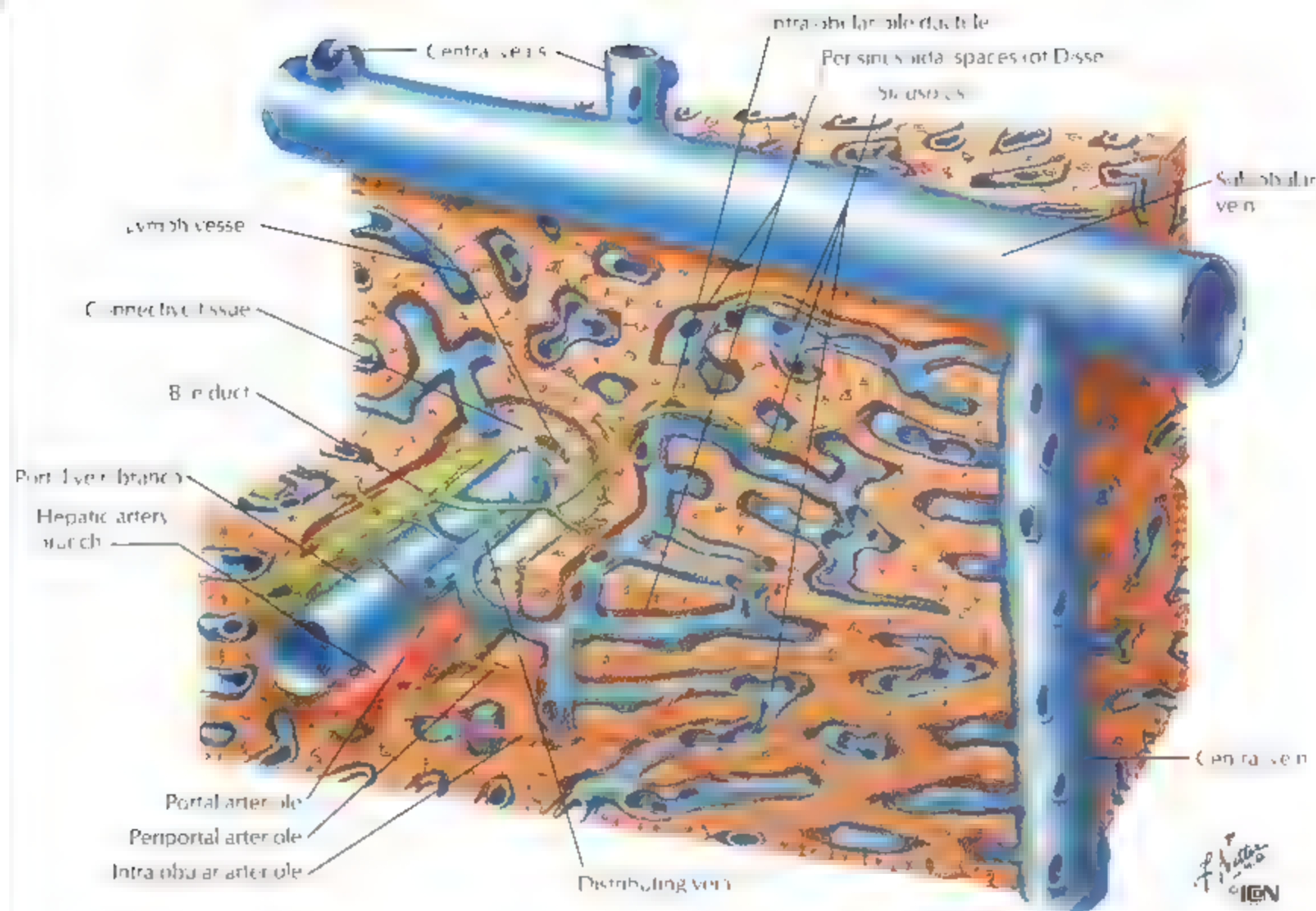
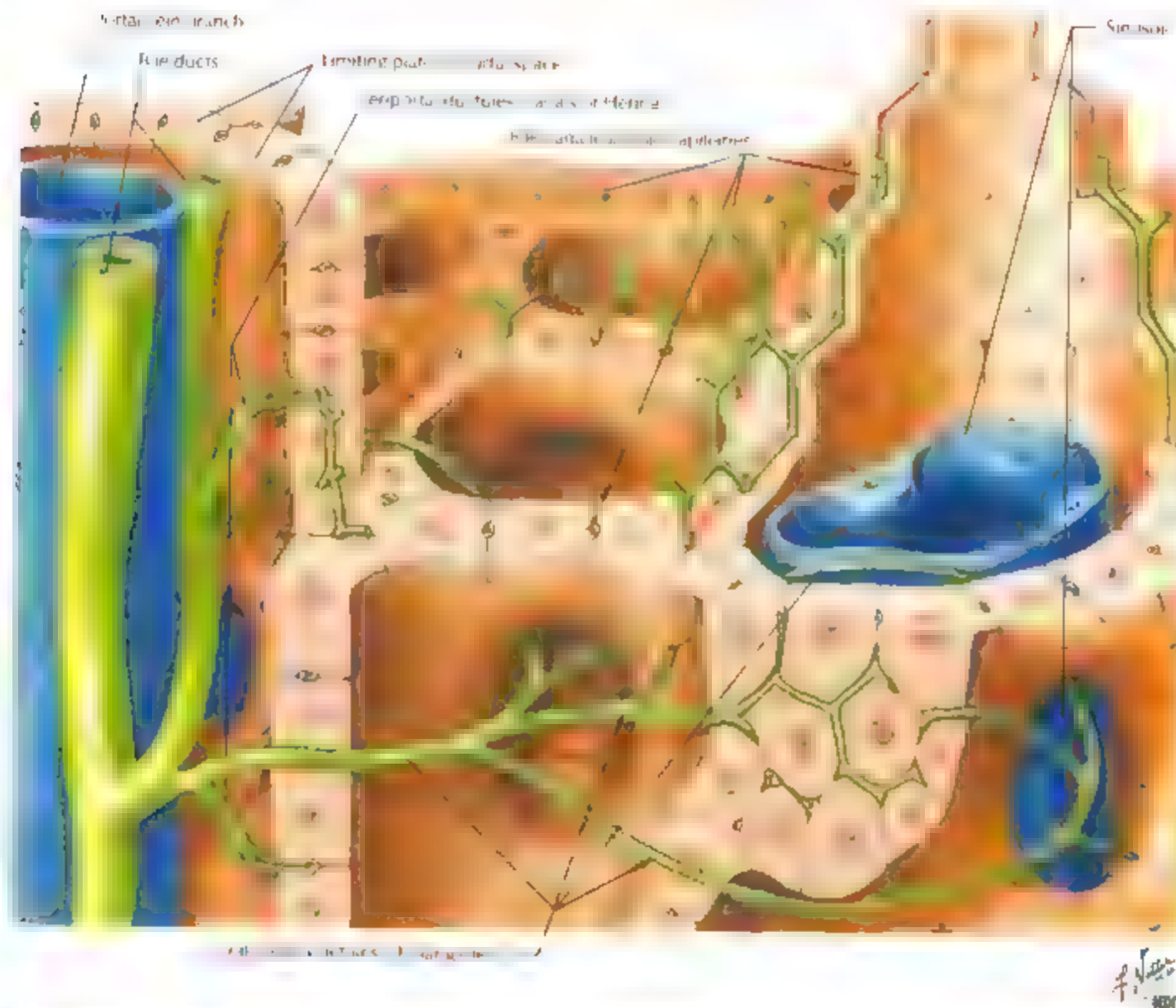


FIGURE 7.29 LIVER ULTRASTRUCTURE

The liver cells (hepatocytes) receive blood from the portal circulation (75%) and from the hepatic artery (25%). Hepatocytes are arranged in plates of cells that are separated from each other by hepatic sinusoids. The blood moves from the portal vein and hepatic arteriole branches through the sinusoids to the central vein. From the central vein, blood flows into the hepatic veins and inferior vena cava. The sinusoids are lined by a discontinuous endothelium that allows free movement of proteins from the blood to the hepatocytes, as well as

from the hepatocytes to the blood. The sinusoids also contain phagocytic cells, Kupfer cells, that clear damaged red blood cells and foreign antigens (not shown). Bile is produced by the hepatocytes and drains into intra-hepatic bile ductules and then larger bile ducts (right and left). The bile ducts consist of the hepatic artery and portal vein. Bile is also secreted into the gallbladder where it is stored and concentrated.



Note: The figure shows the biliary tree structures with a color-coded key. However, the labels are not all in the same color as the structures they point to.

FIGURE 7.30 INTRAHEPATIC BILIARY SYSTEM

The hepatic system enters the bile canaliculi, approximately 100 μm in diameter. Bile flow from the canaliculi into the intrahepatic ducts and the hepatic portal vein ducts that join the hepatic vein and hepatic artery branches. The hepatic

artery carries blood to the hepatic portal system, which carries the blood to the liver. The hepatic portal system is a network of blood vessels that carries blood from the liver and carries it to the liver. The hepatic portal system is a network of blood vessels that carries blood from the liver and carries it to the liver.

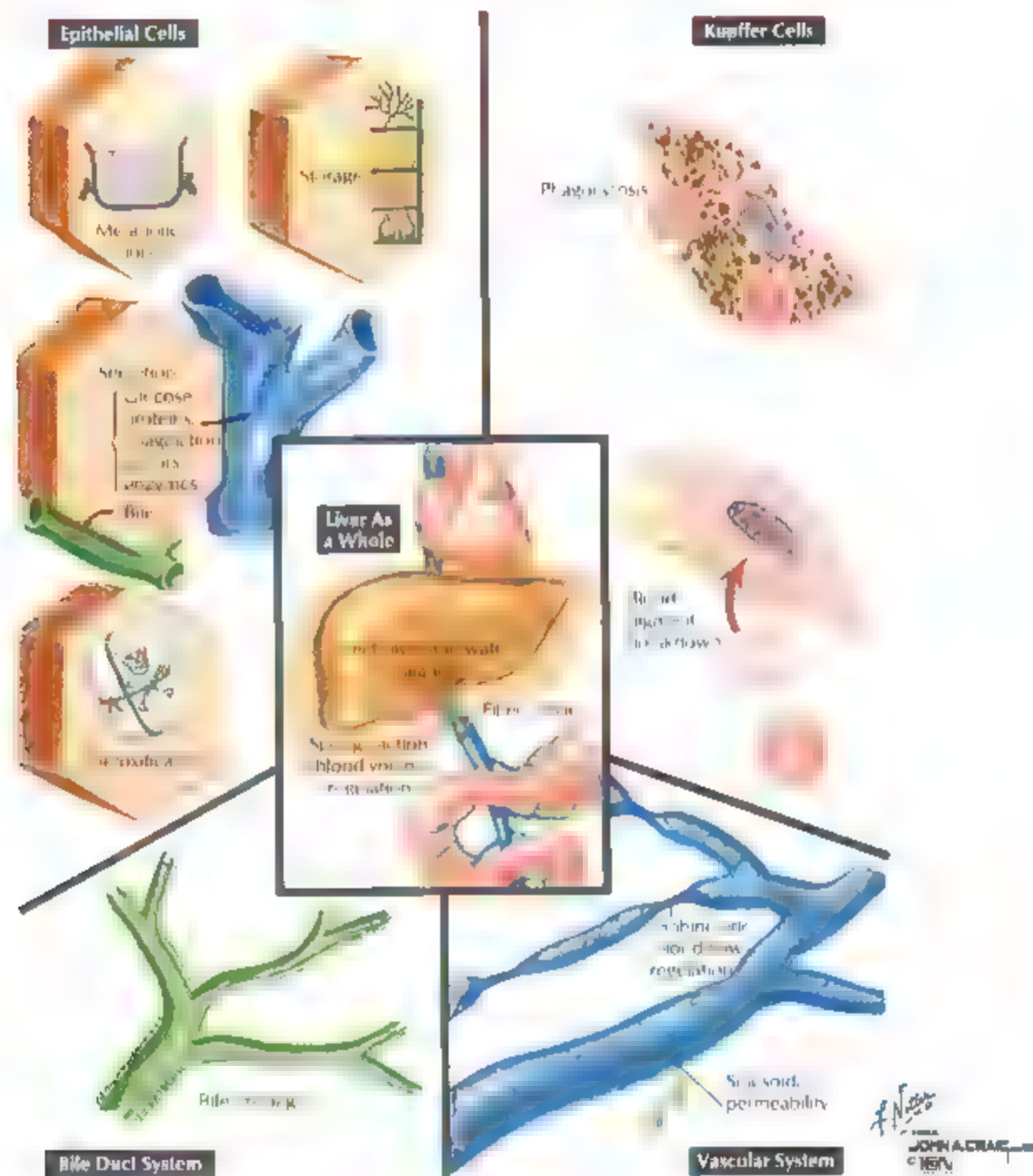
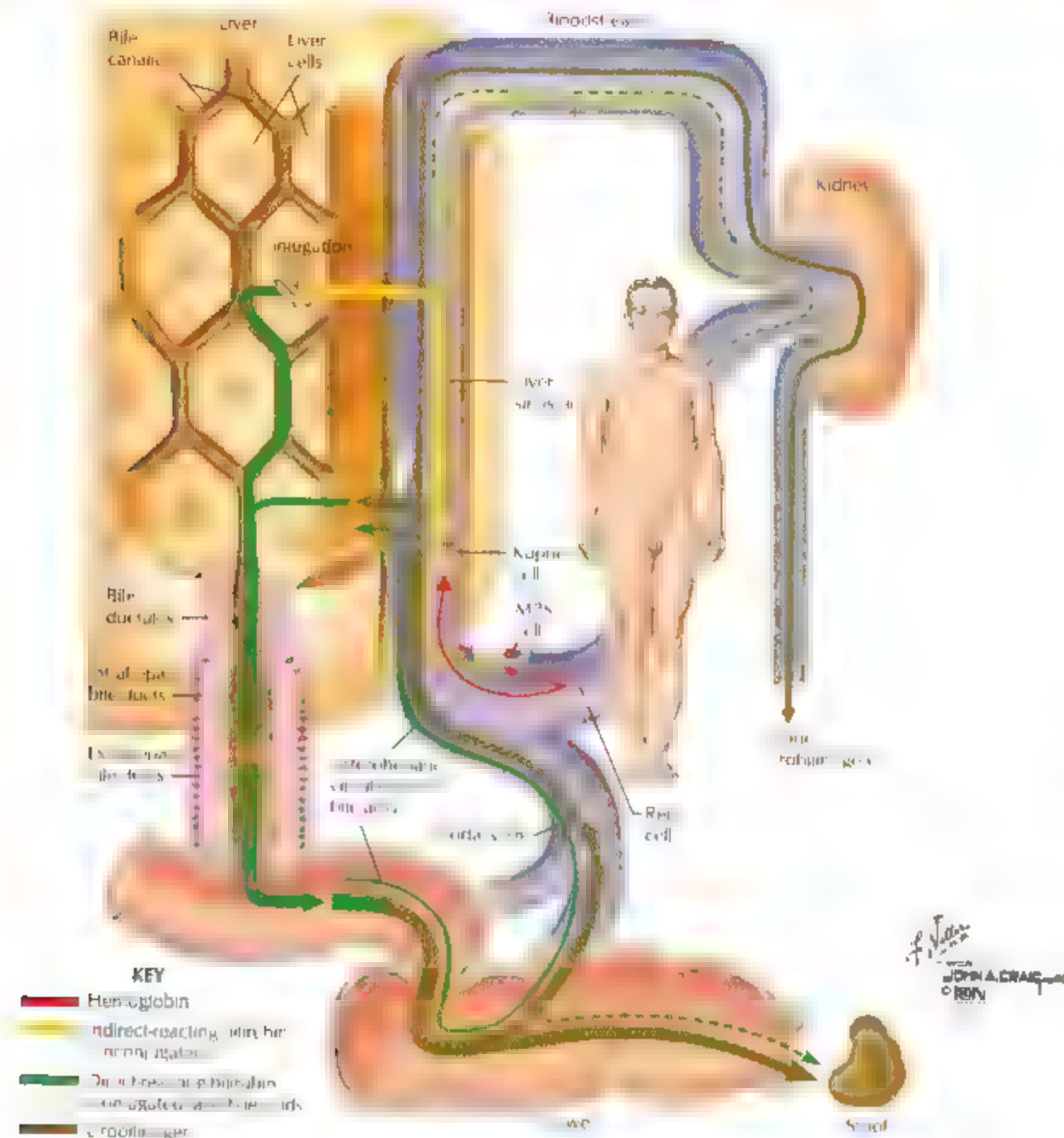


FIGURE 7-31 OVERVIEW OF LIVER FUNCTION

The liver serves a number of important functions, including storage of important nutrients and energy sources (e.g., glycogen, vitamins, and proteins), production of blood cells (e.g., glucose, amino acids, and ketone acids), production of plasma proteins, and detoxification of drugs, chemicals, and toxins. The liver also excretes substances (e.g., bilirubin) and the production of bile acids. The Kupfer cells

phagocytose foreign materials that cross the wall of the portal vein and enter the portal circulation. Cells of the immune system, phagocytic system (MPS), are in the liver. Kupfer cells also secrete the body's phagocytose damaged red blood cells. Bile is secreted by the liver in degradation and excreted by the liver in the bile (see Figure 7-32).



Cells of the mononuclear phagocyte system (MPS), both in the liver (Kupffer cells) and throughout the body, phagocytose damaged red blood cells. Bilirubin, a degradation product of hemoglobin, is released by these cells as conjugated bilirubin. The liver hepatocytes take up this bilirubin and conjugate it with glucuronic acid to form bilirubin glucuronides, which are excreted into the bile. In the intestine the bilirubin glucuronides are converted to urobilinogen by bacterial action. Some of this urobilinogen is absorbed and returned to the liver, which reexcretes

it in the bile. Some of the urobilinogen is also excreted by the kidneys. The bile also contains bile acids, which aid in the digestion of lipids by their ability to emulsify fats and form mixed micelles with the lipid molecules (see Figure 7.37). Bile acids are reabsorbed by the small intestine. Typical of the enterohepatic circulation, the bile acids are recirculated in this manner (enterohepatic circulation). The bile acids in the liver each day are replaced by hepatic synthesis.

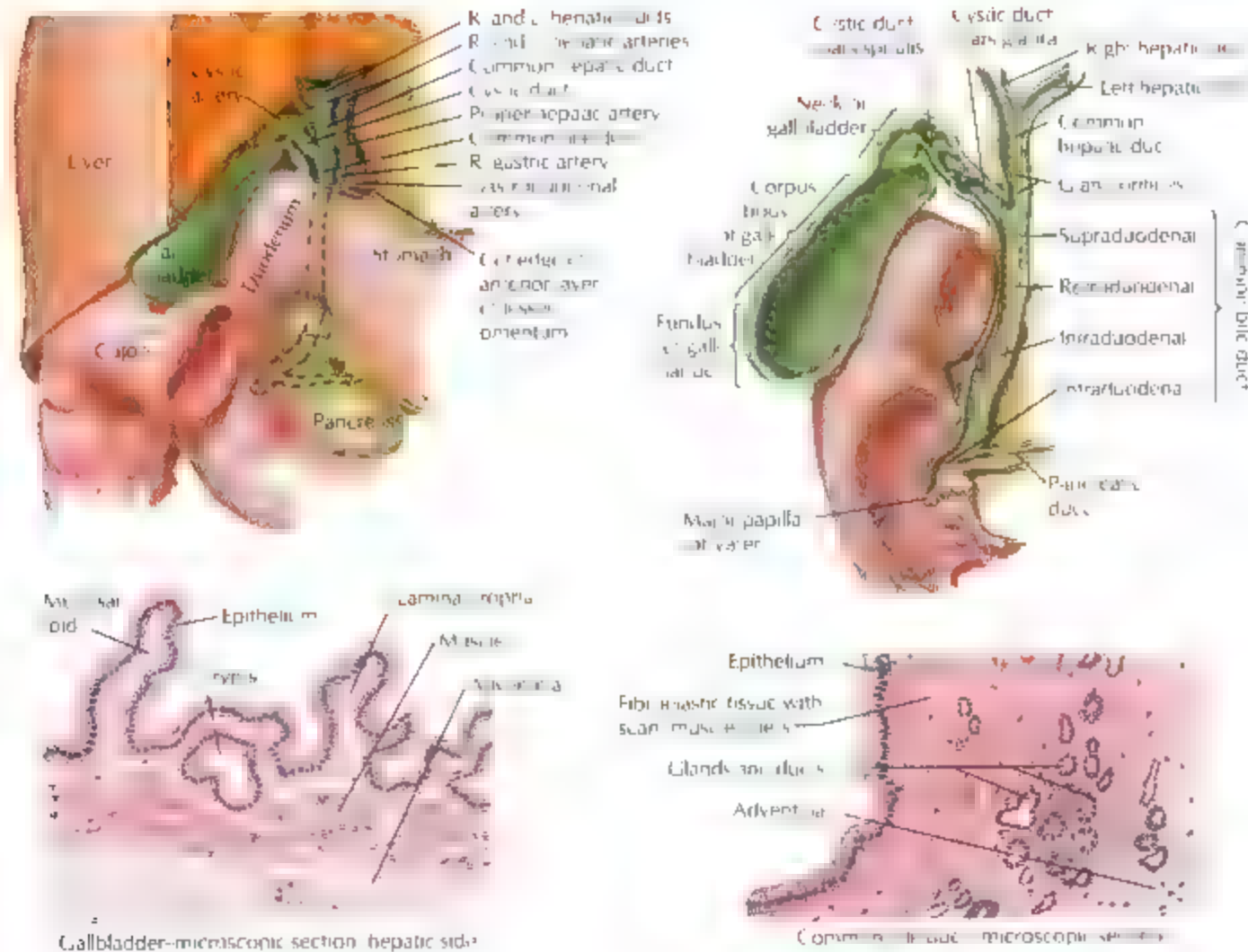
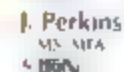


FIGURE 7.33 GALLBLADDER STRUCTURE AND FUNCTION

The gallbladder is a small, yellow organ that is located in the upper right quadrant of the abdomen. It serves to store and concentrate the bile synthesized by the liver. The gallbladder holds about 20 to 50 mL of bile. Vagal stimulation and cholecystokinin released by the endocrine cells in the duodenum in response to the presence of fat cause the gallbladder to contract

and transport bile down the cystic duct and into the common bile duct, where it empties into the second descending portion of the duodenum. The gallbladder mucosa is specialized for electrolyte and water absorption, which allows the gallbladder to concentrate the bile.



GI TRACT FLUID AND ELECTROLYTE TRANSPORT

a large number of different ways and should be handled accordingly. The selected one helps maintain the best possible condition of the road surface. Naturally, the use of a road agent will only be justified if it is supported by only a few, but effective measures in the field of maintenance, such as the following: a) patching. But the use of a road agent is absorption and drainage.

+ the transmembrane transport mechanism is a Na^+ -dependent symporter, where the Na^+ gradient $\Delta\mu_{\text{Na}}$ is used to drive either Na^+ or glucose down its gradient. F_1F_0 ATPase is an H^+ -translocase, which is a transmembrane transport protein, and F_1 is located in the cytosol. All H^+ in a membrane are so we have $\Delta\mu_{\text{H}^+} = \Delta\mu_{\text{F}}$. If multiple transducer systems with these all together, we can express a whole cell.



FIGURE 7.35 DIGESTION OF PROTEIN

Protein digestion begins in the mouth, where salivary amylase is secreted. The majority of protein digestion occurs in the stomach, where gastric juice (containing hydrochloric acid and pepsin) is secreted. The small intestine is the site of the final stages of protein digestion, where pancreatic juice (containing trypsin, chymotrypsin, and amylase) and brush border enzymes (maltase, sucrase, and lactase) are secreted. The large intestine is responsible for the absorption of water and the formation of feces. The rectum is the final storage site for feces before elimination.

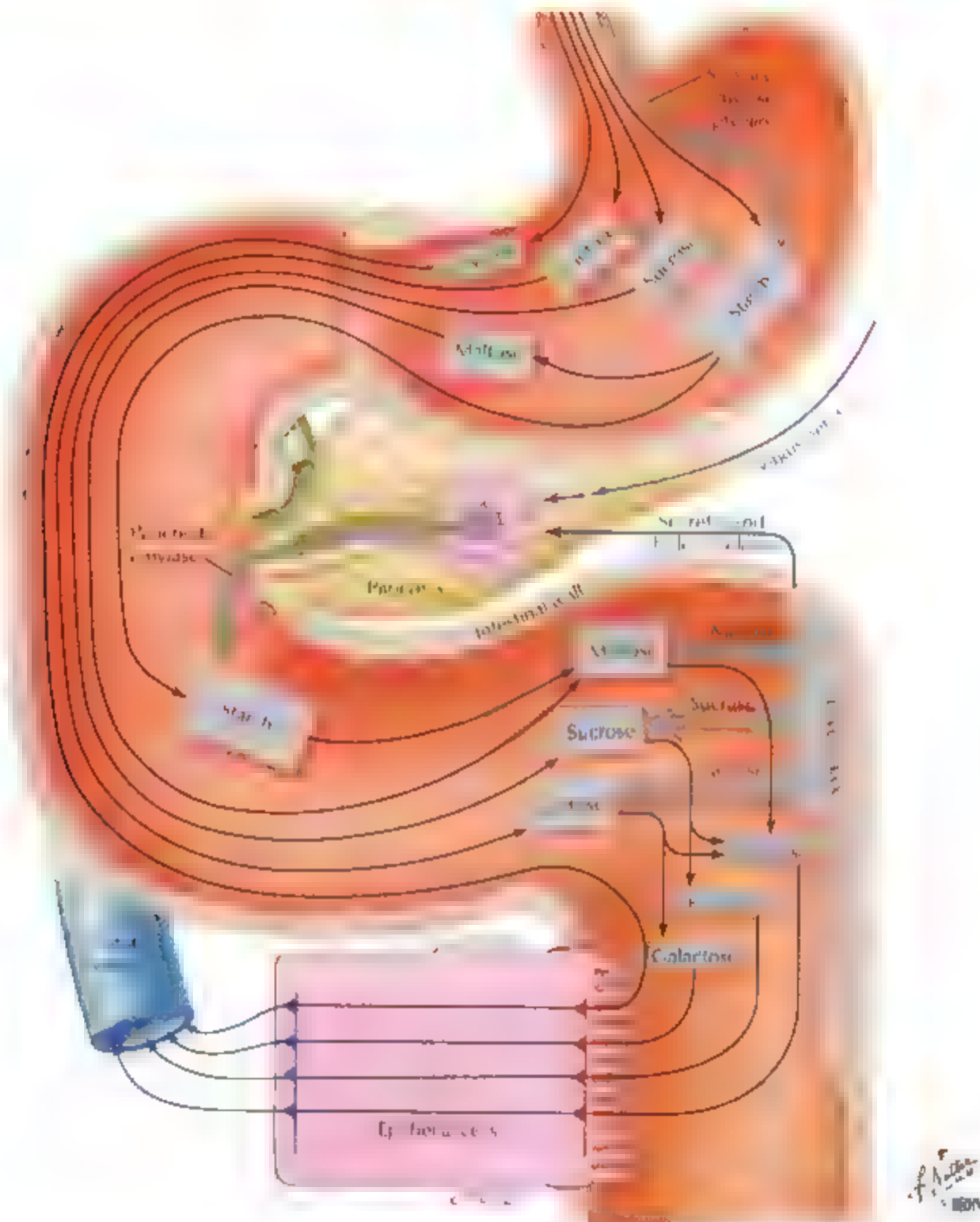


FIGURE 7.36 DIGESTION OF CARBOHYDRATES

Digestion of carbohydrates and absorption begins in the mouth and continues through the action of salivary amylase, pancreatic amylase, and intestinal amylase. In the small intestine, the monosaccharides glucose, fructose, and galactose are absorbed. The glycerol and fatty acids continue this process, yielding monosaccharides. The glycerol and fatty acids are absorbed by the intestinal epithelium and enter the bloodstream.

Glucose is absorbed by the intestinal epithelium. The monosaccharides are absorbed by the intestinal epithelium and enter the bloodstream. The glycerol and fatty acids are absorbed by the intestinal epithelium and enter the bloodstream.

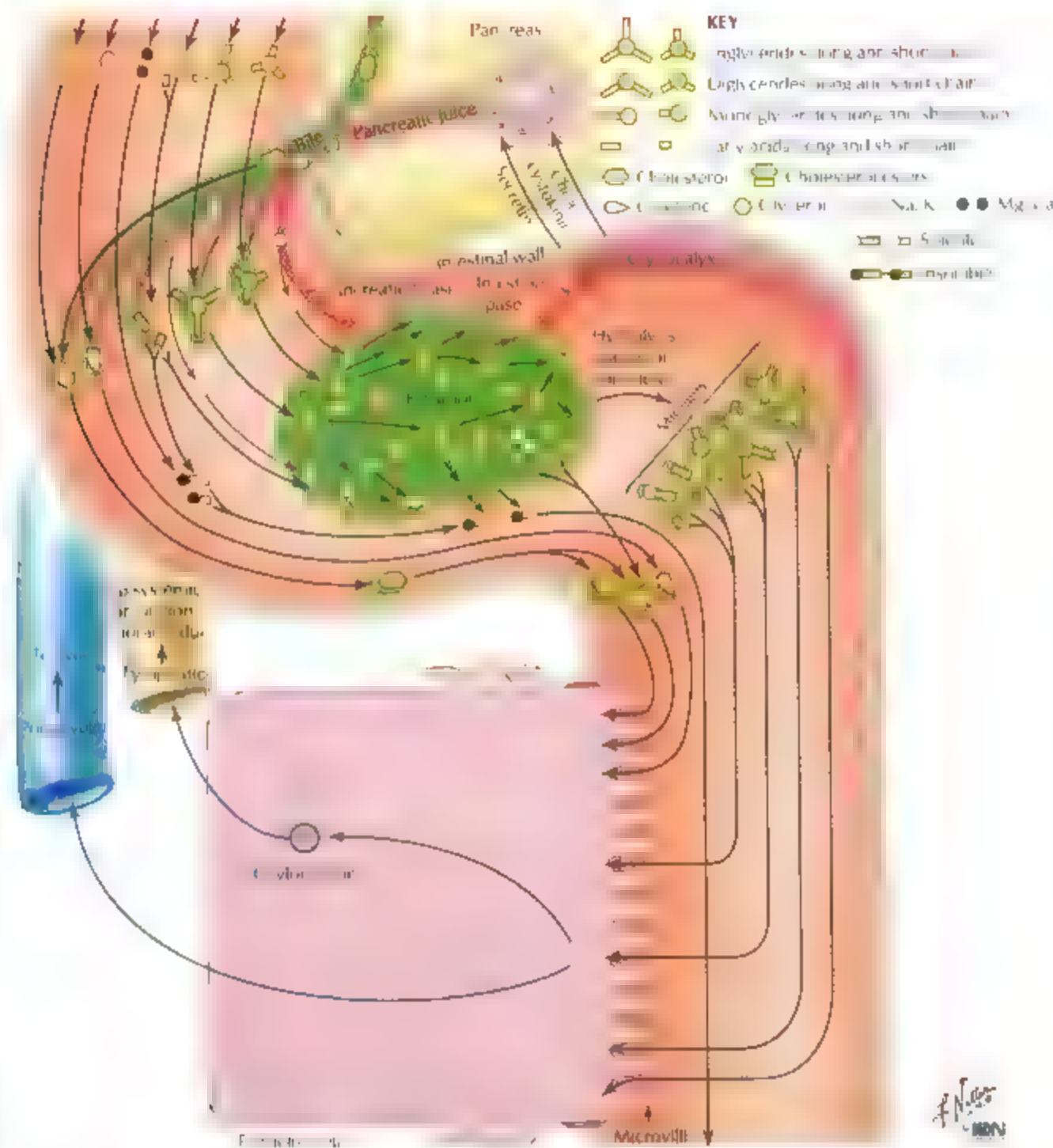
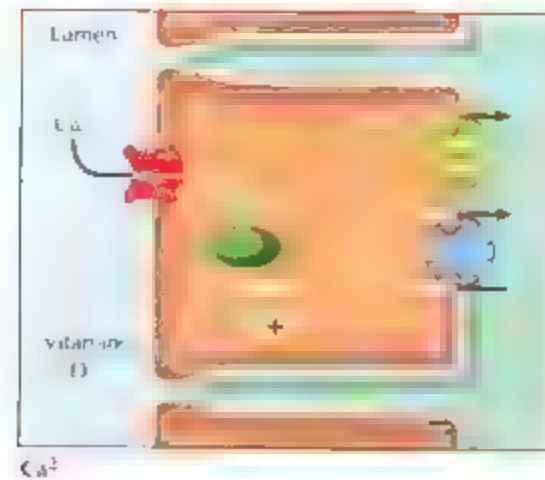


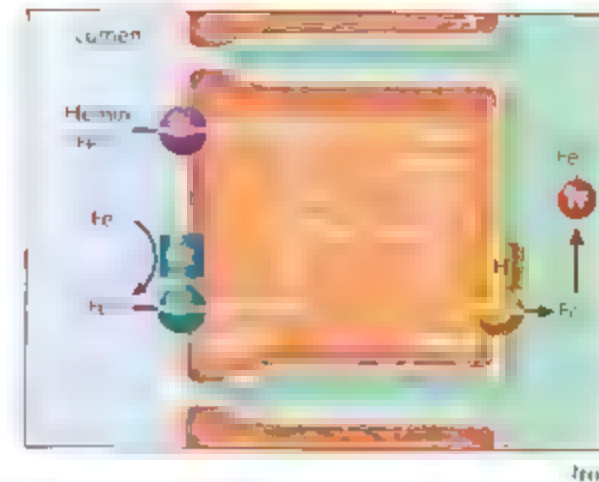
FIGURE 7-37 DIGESTION OF FAT

Although some lipid digestion begins in the non-acid stomach, most digestion is in the small intestine, largely by the action of pancreatic lipase. Lipase is secreted by the pancreas and acts on the emulsified fat droplets in the intestinal lumen. The bile salts act as emulsifiers, increasing the surface area of the fat droplets. The products of fat digestion are absorbed by the intestinal mucosa and enter the lymphatic system via the lacteals. The main products are monoglycerides and free fatty acids.

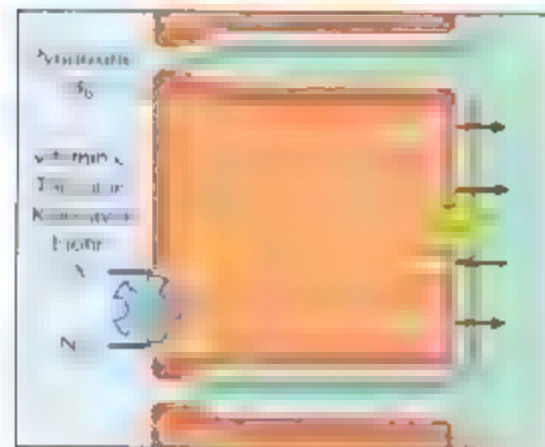
Cholesterol is absorbed as free cholesterol or as cholesterol esters. For the purpose of storage within the epithelial cells, cholesterol is esterified, and these cholesterol esters are excreted in the bile. The bile salts act as emulsifiers, increasing the surface area of the fat droplets. The products of fat digestion are absorbed by the intestinal mucosa and enter the lymphatic system via the lacteals. The main products are monoglycerides and free fatty acids.



Ca²⁺

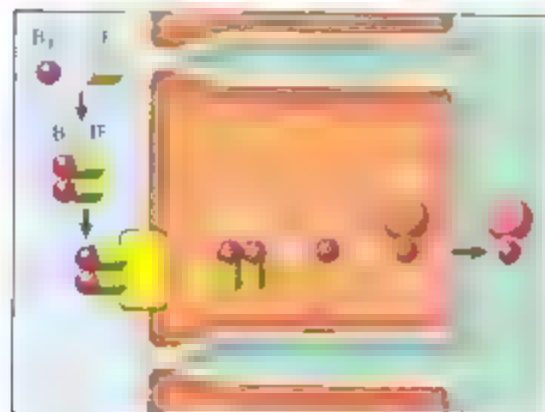


Iron



Water-Soluble Vitamins

Element	Site of Absorption	Mechanism
Ca	duodenum	Active
Fe	duodenum	Facilitated diffusion
Water-Soluble Vitamins		
Vitamin A	duodenum	Passive diffusion
Vitamin B	duodenum	Passive diffusion
Vitamin C	duodenum	Passive diffusion
Vitamin D	duodenum	Passive diffusion
Vitamin E	duodenum	Passive diffusion
Vitamin K	duodenum	Passive diffusion
Fat-Soluble Vitamins		
Vitamin A	duodenum	Passive diffusion
Vitamin B	duodenum	Passive diffusion
Vitamin C	duodenum	Passive diffusion
Vitamin D	duodenum	Passive diffusion
Vitamin E	duodenum	Passive diffusion
Vitamin K	duodenum	Passive diffusion



Vitamin B₁₂



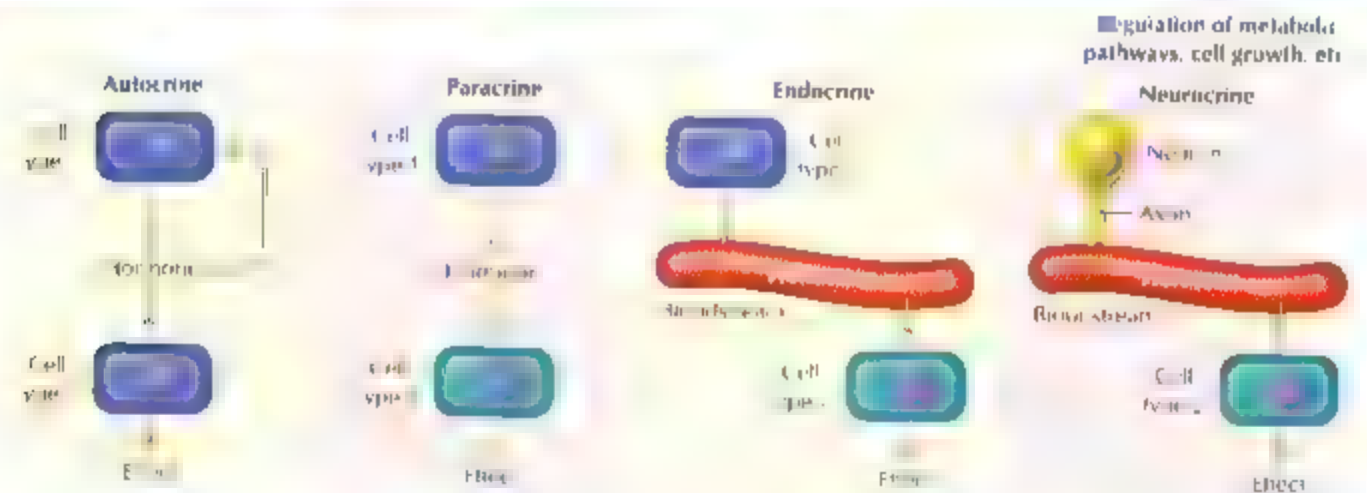
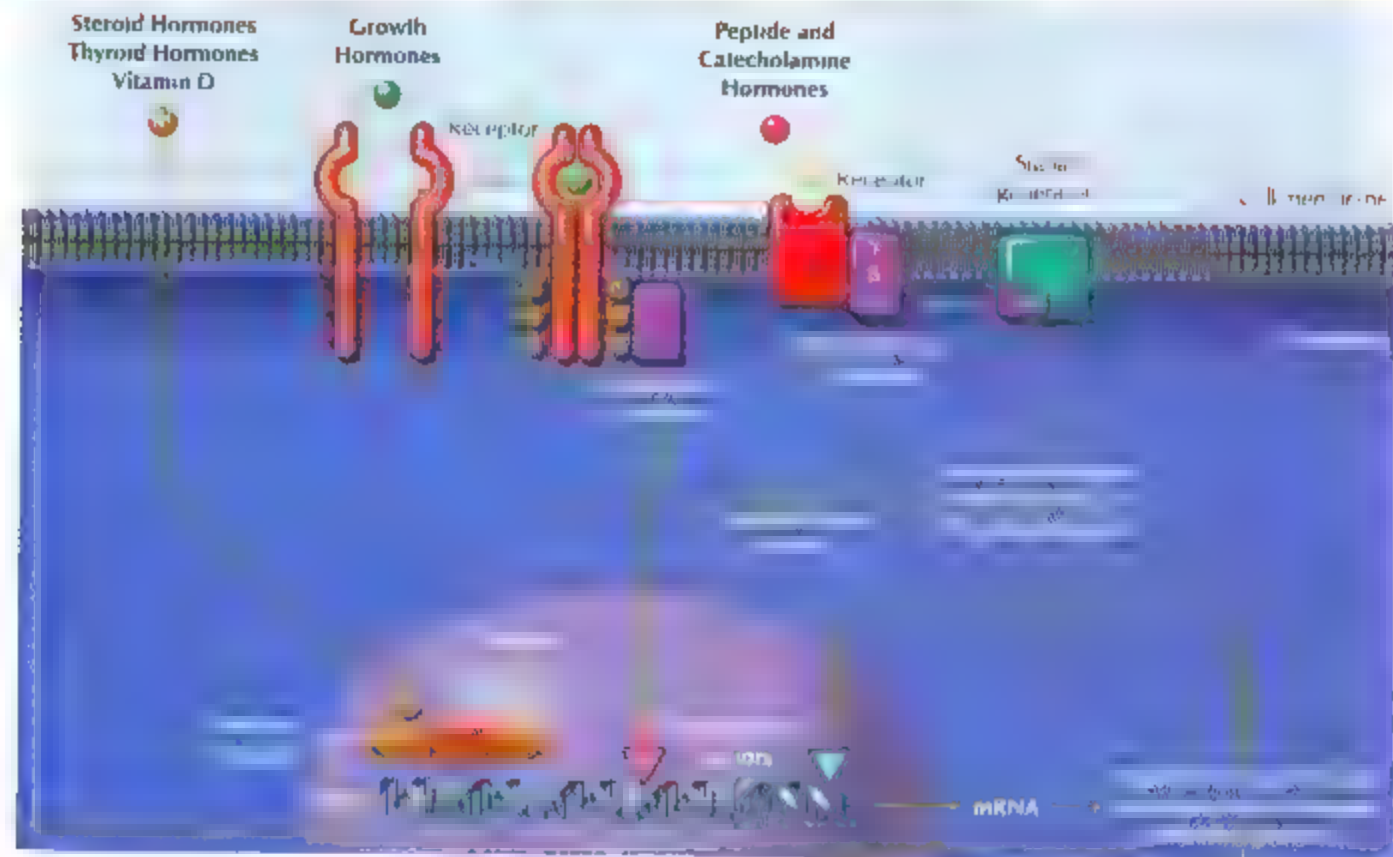
Fat-Soluble Vitamins

J. Perkins
MS, MPA
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FIGURE 7.38 ABSORPTION OF ESSENTIAL VITAMINS AND ELEMENTS

The primary mechanism of absorption for most vitamins and elements is passive diffusion. However, some vitamins and elements are absorbed through active transport mechanisms. For example, calcium is absorbed through active transport mechanisms in the duodenum. Iron is absorbed through facilitated diffusion mechanisms in the duodenum. Water-soluble vitamins are absorbed through passive diffusion mechanisms in the duodenum. Fat-soluble vitamins are absorbed through passive diffusion mechanisms in the duodenum.

Calcium is absorbed through active transport mechanisms in the duodenum. Iron is absorbed through facilitated diffusion mechanisms in the duodenum. Water-soluble vitamins are absorbed through passive diffusion mechanisms in the duodenum. Fat-soluble vitamins are absorbed through passive diffusion mechanisms in the duodenum.



Perkins
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FIGURE 8.1 OVERVIEW OF HORMONE ACTION

Hormones are involved in the process of cell-to-cell signaling. They are released by one cell and bind to a specific receptor on another cell. The receptor may be in the plasma membrane or in the cytoplasm or nucleus. The hormone binds to the receptor and activates a second messenger or a signaling pathway.

The effect of the hormone on the cell may be to increase or decrease the rate of a metabolic pathway, to increase or decrease the rate of protein synthesis, or to increase or decrease the rate of cell division. The diagram illustrates the different ways in which hormones can act on a cell.

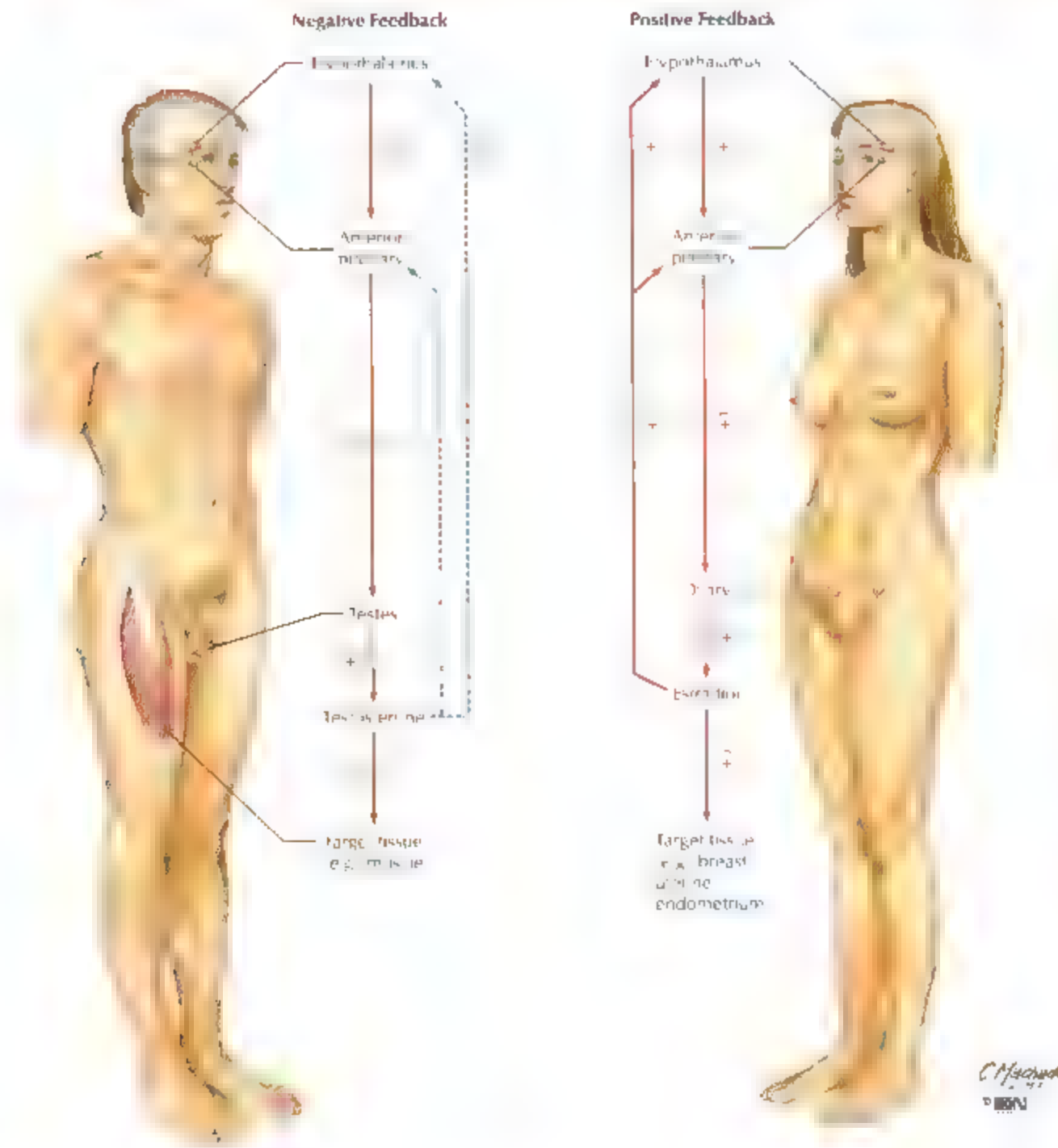


FIGURE 8.2 FEEDBACK REGULATION

Hormone secretion is regulated by both negative feedback mechanisms (e.g., testosterone) and positive feedback mechanisms (e.g., estrogen during phase II of the menstrual cycle).

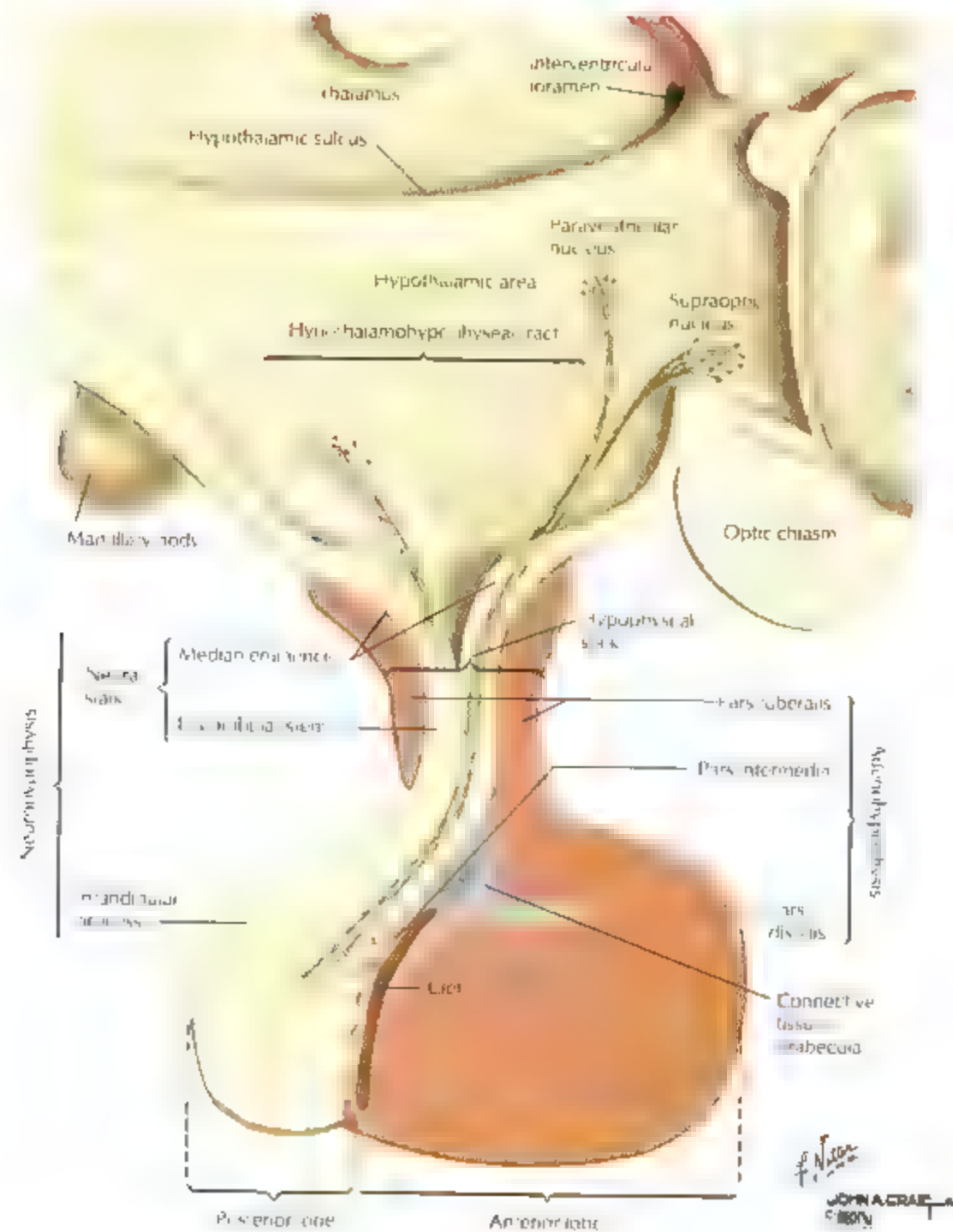


FIGURE 8.3 STRUCTURE OF HYPOTHALAMUS AND PITUITARY

The adenohypophysis (aden = primary) is formed as a downward growth of the diencephalon of the brain. The apenohypophysis (apen = primary) is derived from the ectoderm, which is the same as the epidermis. The intermediate lobe is not well developed in humans. Neuroendocrine cells in the hypothalamus send

axons into the posterior pituitary and in the region of the median eminence. Hormones are released from these axons into the systemic blood, portal system, or into the hypothalamic-hypophyseal portal system (see Figure 8.4). In the region of the median

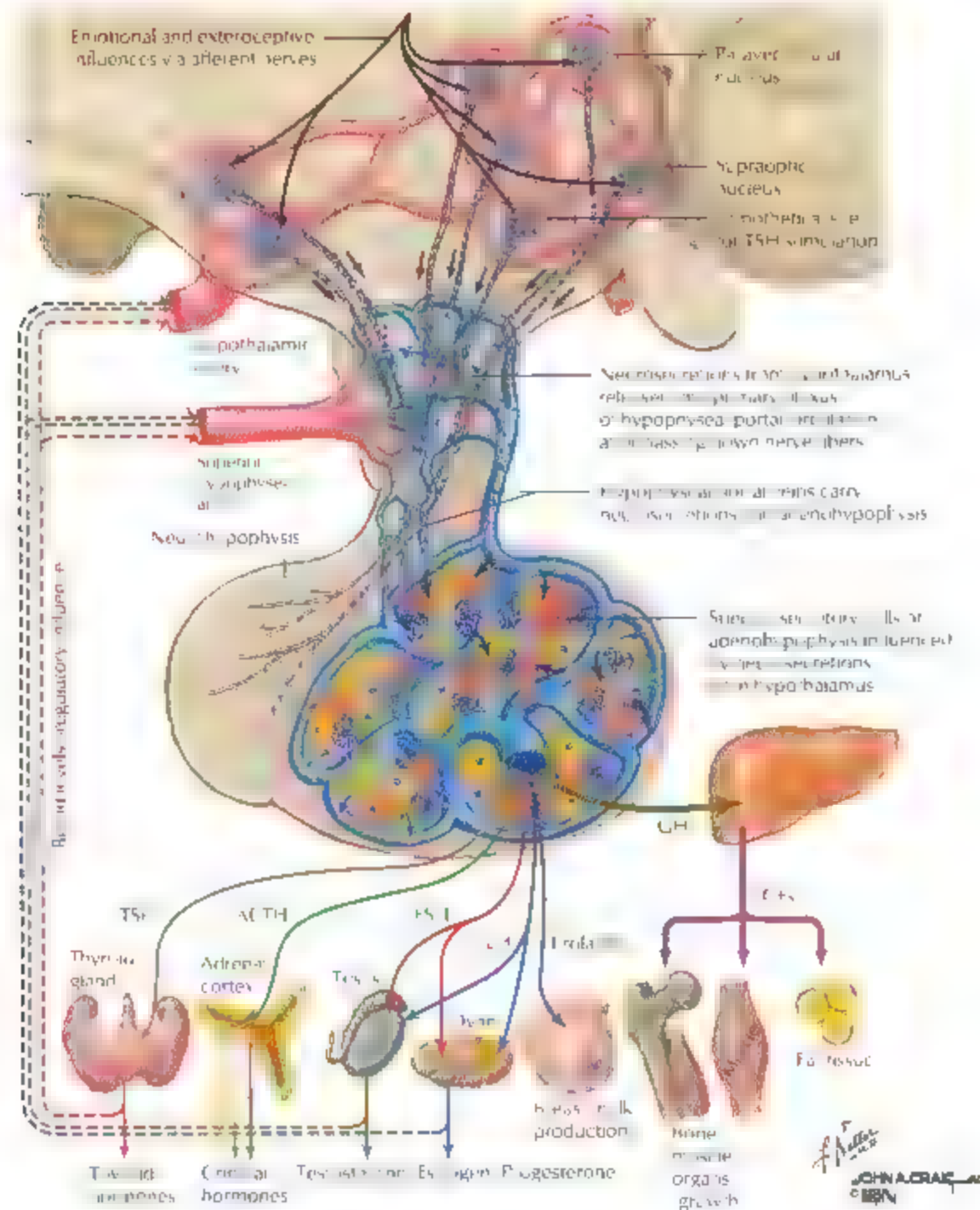


FIGURE 8-4 OVERVIEW OF ANTERIOR PITUITARY FUNCTION

Hypothalamic neuroendocrine cells release hormones into the hypophyseal-hypophyseal portal system that stimulate or inhibit the secretory cells of the anterior pituitary. Under the control of these hypothalamic releasing and inhibiting hormones, the cells of the anterior pituitary release hypophyseal hormones which have an effect on

endocrine glands. The hormones secreted by the endocrine glands feed back on both the cells of the anterior pituitary and the hypothalamus to regulate the secretion of tropic hormones and release of hormones.

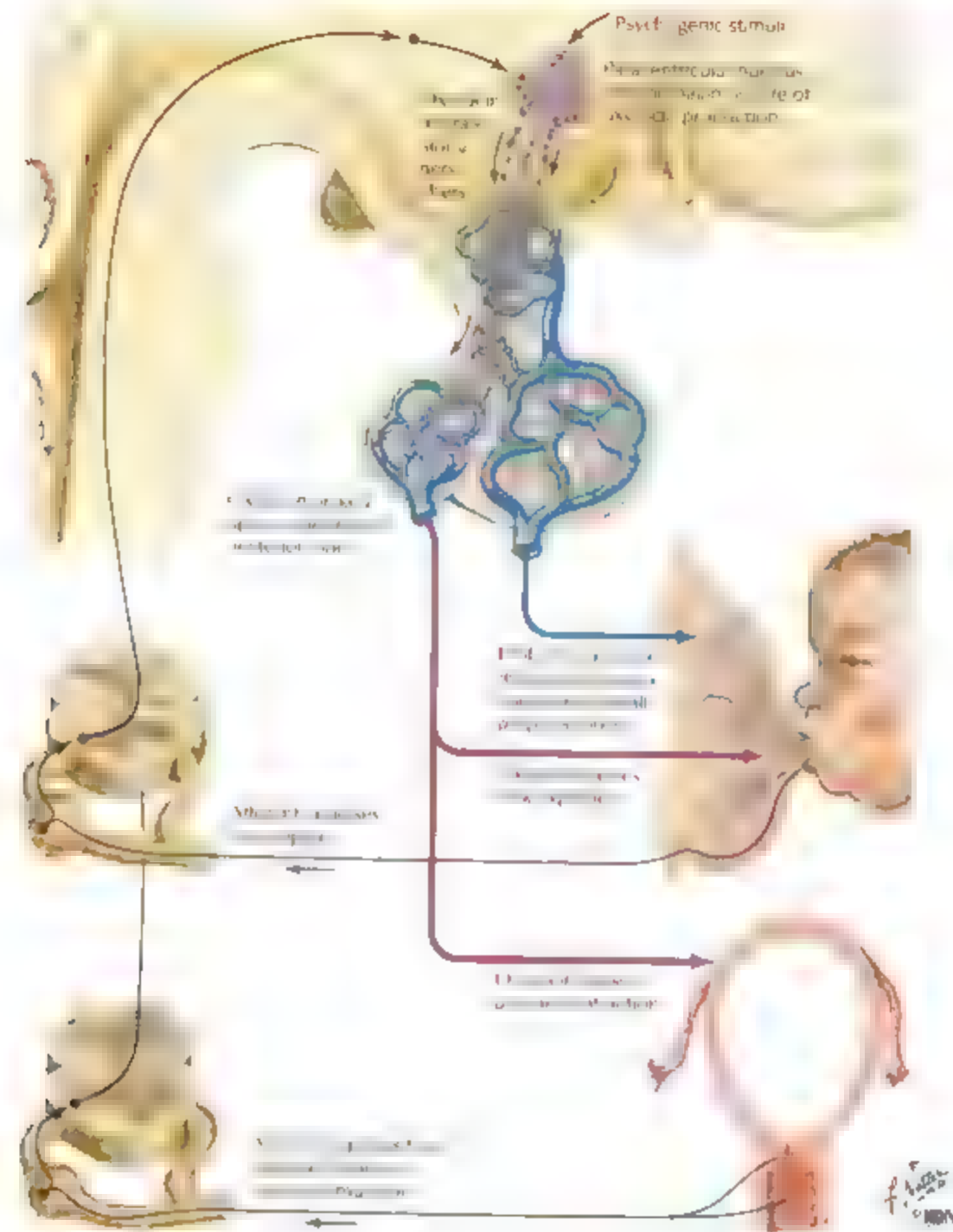


FIGURE 8.5 POSTERIOR PITUITARY FUNCTION (OXYTOCIN)

Oxytocin is released from the posterior pituitary in response to a stimulus from the hypothalamus. It causes uterine contraction during childbirth and milk ejection from the mammary glands. It also causes relaxation and stress reduction in the brain. The diagram shows the hypothalamus, pituitary gland, and the general circulation. The hypothalamus contains oxytocin-producing cells. A psychogenic stimulus triggers the release of oxytocin from these cells into the neurohypophysis (posterior pituitary). From there, oxytocin travels through the infundibular stalk to the anterior pituitary and is released into the general circulation. The diagram shows oxytocin acting on several target organs: Uterus: Oxytocin causes uterine contraction, leading to childbirth. Mammary Glands: Oxytocin causes milk ejection. Heart: Oxytocin causes heart contraction, leading to increased blood flow. Brain: Oxytocin acts on the brain to cause relaxation and stress reduction. Feedback loops are shown where these effects (e.g., childbirth, milk ejection) provide negative feedback to the hypothalamus to inhibit further oxytocin release.

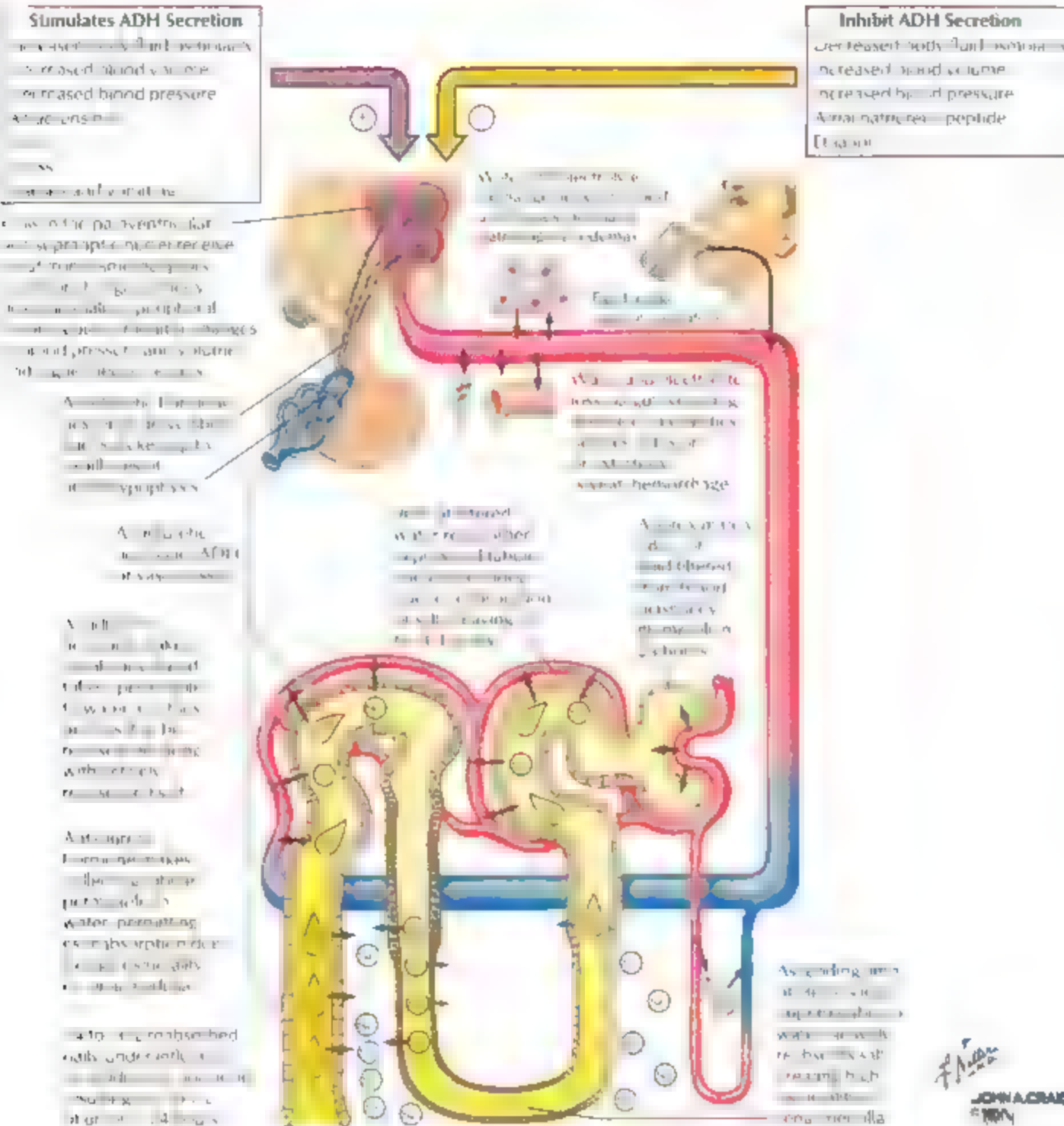


FIGURE 8.6 POSTERIOR PITUITARY FUNCTION (ADH)

With the normal ADH concentration, a large volume of dilute urine is excreted. When ADH levels are elevated, a small volume of concentrated urine is excreted. When ADH levels are low, a large volume of dilute urine is excreted.

secretion (see also Figure 8.4). When ADH levels are elevated, a small volume of concentrated urine is excreted. When ADH levels are low, a large volume of dilute urine is excreted.

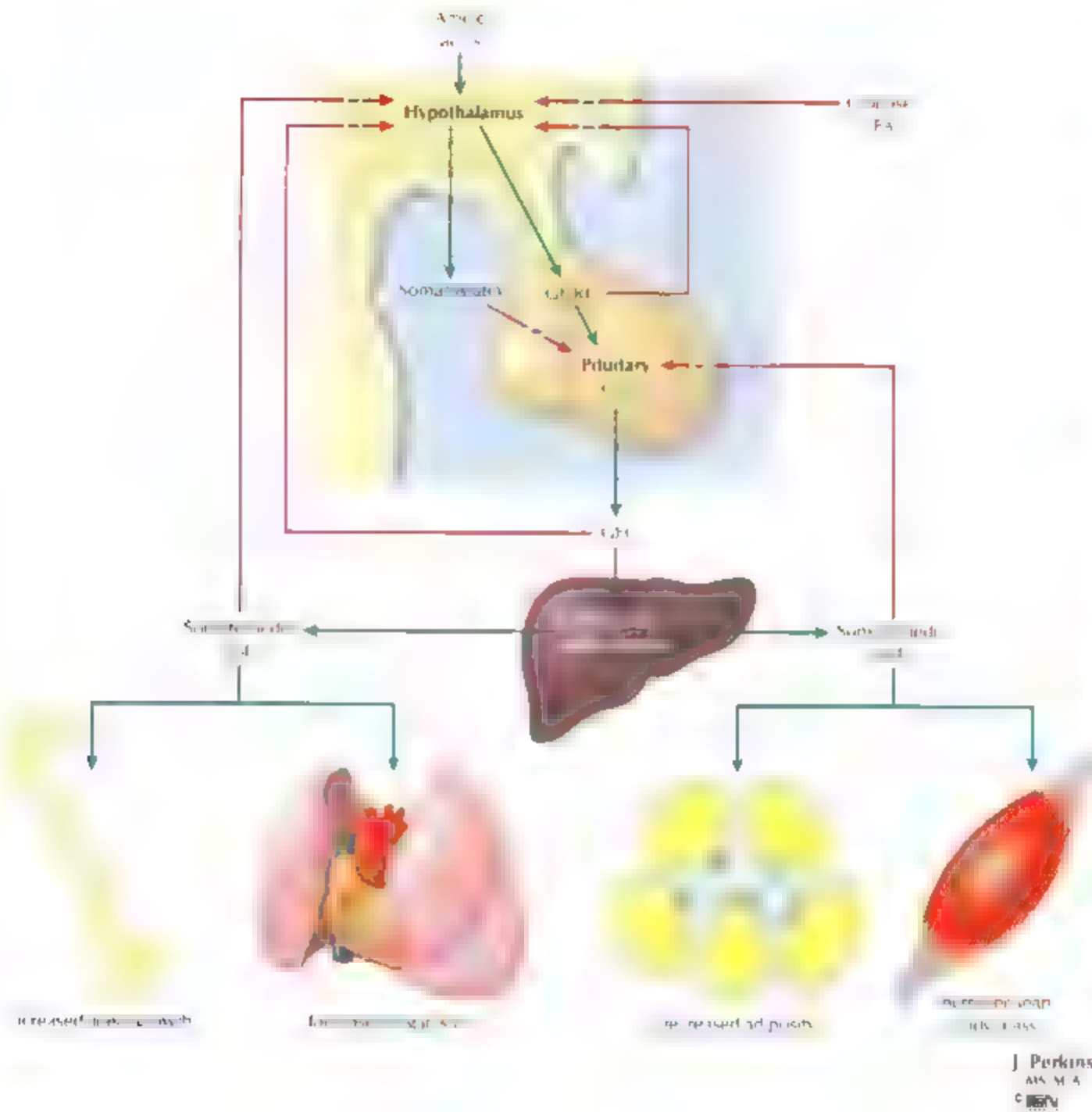


FIGURE 8.7 GROWTH HORMONE

Growth hormone's major physiological effect is somatotropic growth and development in children and adolescents. GH is the major factor in regulating growth with nutrition, genetics, and other factors. GH acts through the growth hormone receptor and the release of somatomedins such as somatomedin C (IGF-1). GH also stimulates the release of fatty acids from adipose tissue.

Growth hormone also stimulates the release of fatty acids from adipose tissue. GH acts through the growth hormone receptor and the release of somatomedins such as somatomedin C (IGF-1). GH also stimulates the release of fatty acids from adipose tissue.

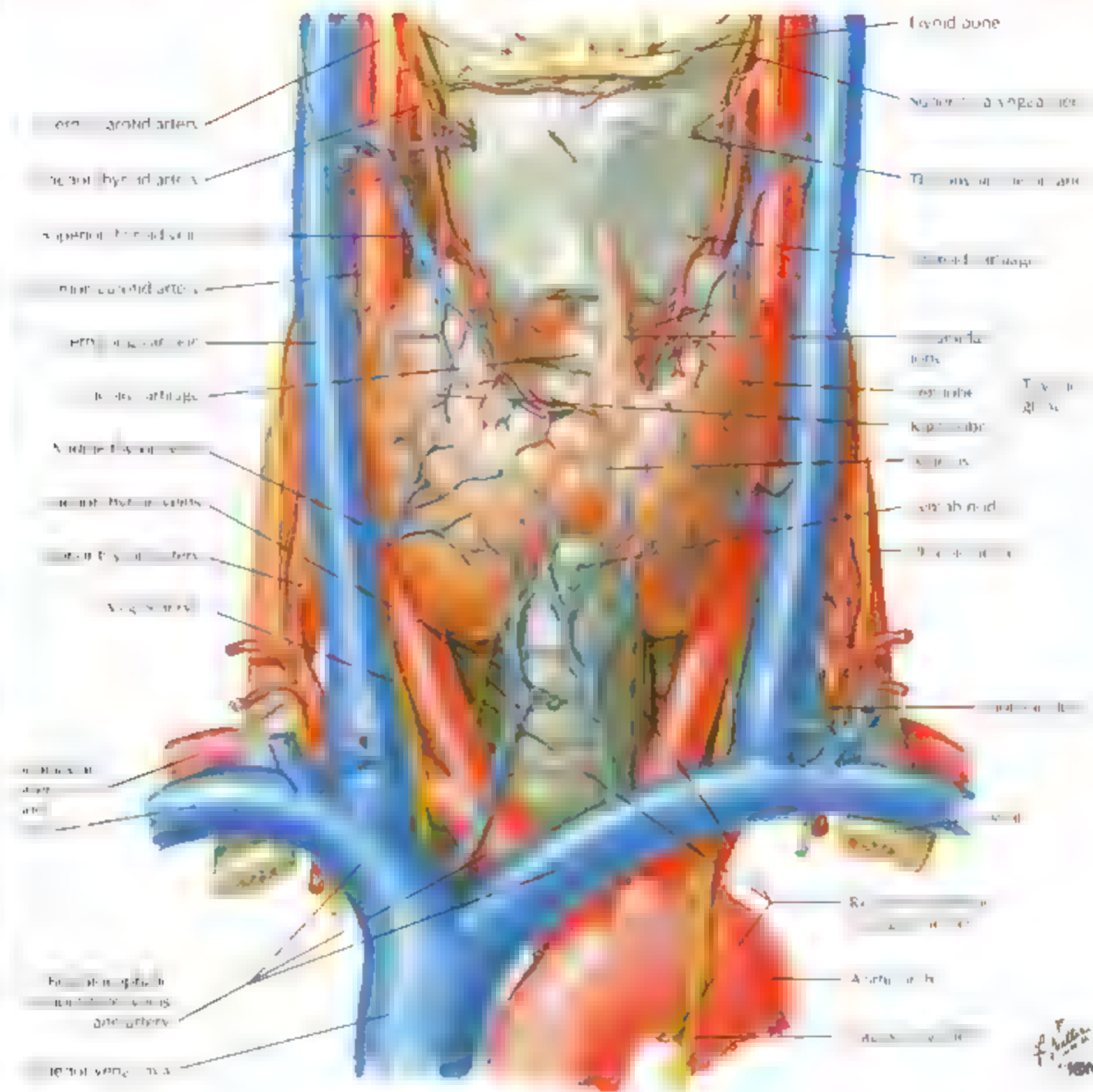


FIGURE 8.8 THYROID GLAND STRUCTURE

The thyroid gland is a ductless, endocrine gland that is located in the neck. It is composed of two lobes and a central isthmus. The thyroid gland is responsible for the production and secretion of thyroid hormones, which are essential for the regulation of metabolism.

In this diagram, the thyroid gland is shown in relation to the trachea and larynx. The superior thyroid artery and vein are shown supplying and draining the upper part of the gland, while the inferior thyroid artery and vein supply and drain the lower part. The vagus nerve and its recurrent laryngeal branch are also shown.



The thyroid gland is comprised of follicles formed by epithelial cells. These follicular epithelial cells synthesize, store, and secrete thyroxine (T_4) and triiodothyronine (T_3). The thyroid gland actively takes up iodide, iodates tyrosine molecules, $ATP \rightarrow$ moniodotyrosine (MIT) = diiodotyrosine, couples these together $\rightarrow T_4$ and T_3 and stores these in the colloid (extracellular space) in the form of a colloid.

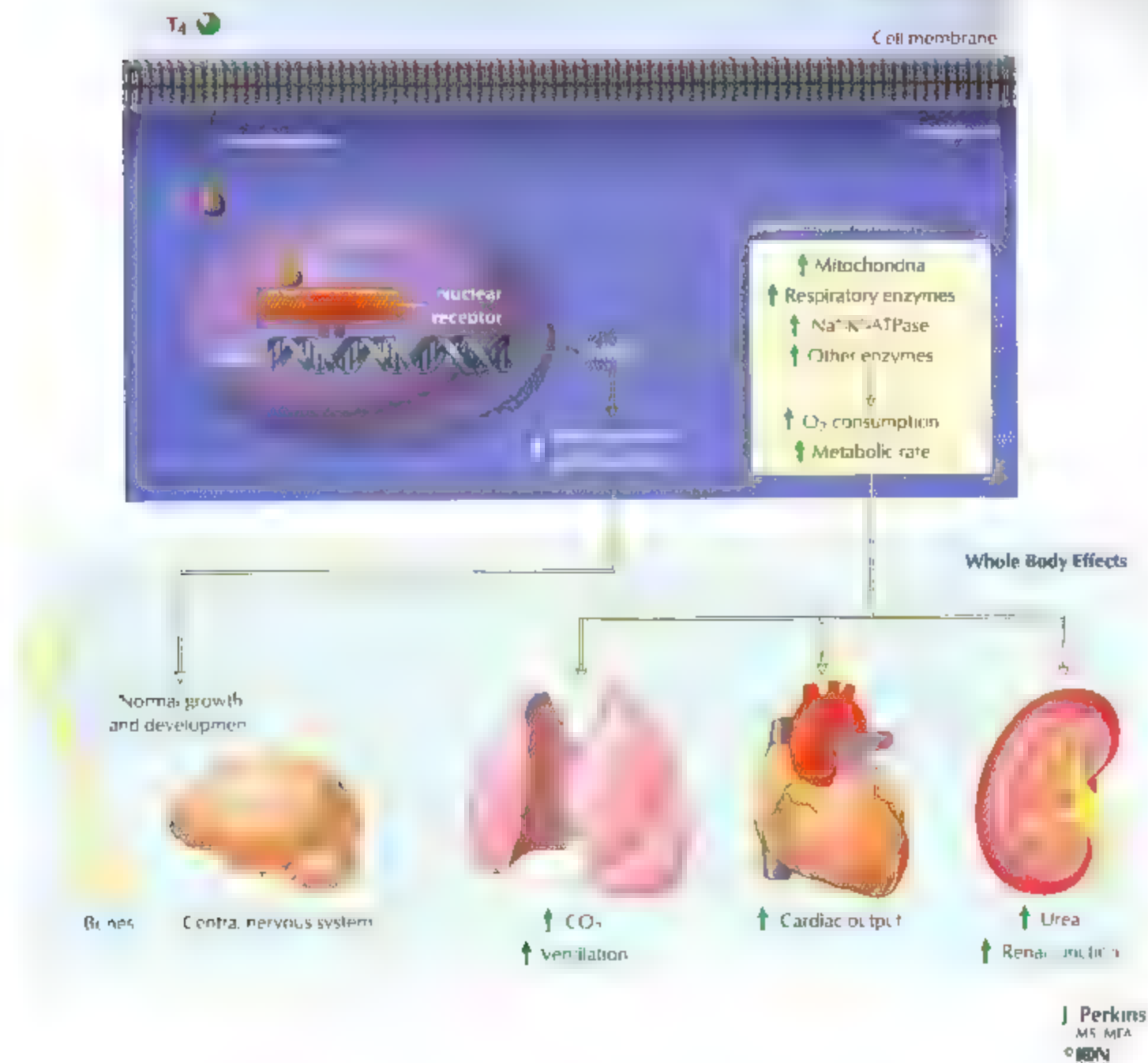


FIGURE 8.10 THYROID HORMONE ACTION

Thyroxine (T_4) is converted to triiodothyronine (T_3) in target tissues. T_3 binds to a nuclear receptor, resulting in transcription of a long-chain cellular protein and enzymes. The net effect is a marked increase in

metabolic rate and O_2 consumption. These effects are associated with increased heart, lung, and kidney function. T_4 is also important for normal growth and development.



The general idea is that every point x in the space is associated with a value $f(x)$. The function f is called the *potential function*. The value of $f(x)$ is the *potential energy* of the system at point x . The total energy of the system is the sum of the potential energy and the kinetic energy. The total energy is conserved. The system moves from one point to another if the total energy is greater than the potential energy at the new point. The system moves from one point to another if the total energy is less than the potential energy at the new point. The system moves from one point to another if the total energy is equal to the potential energy at the new point.

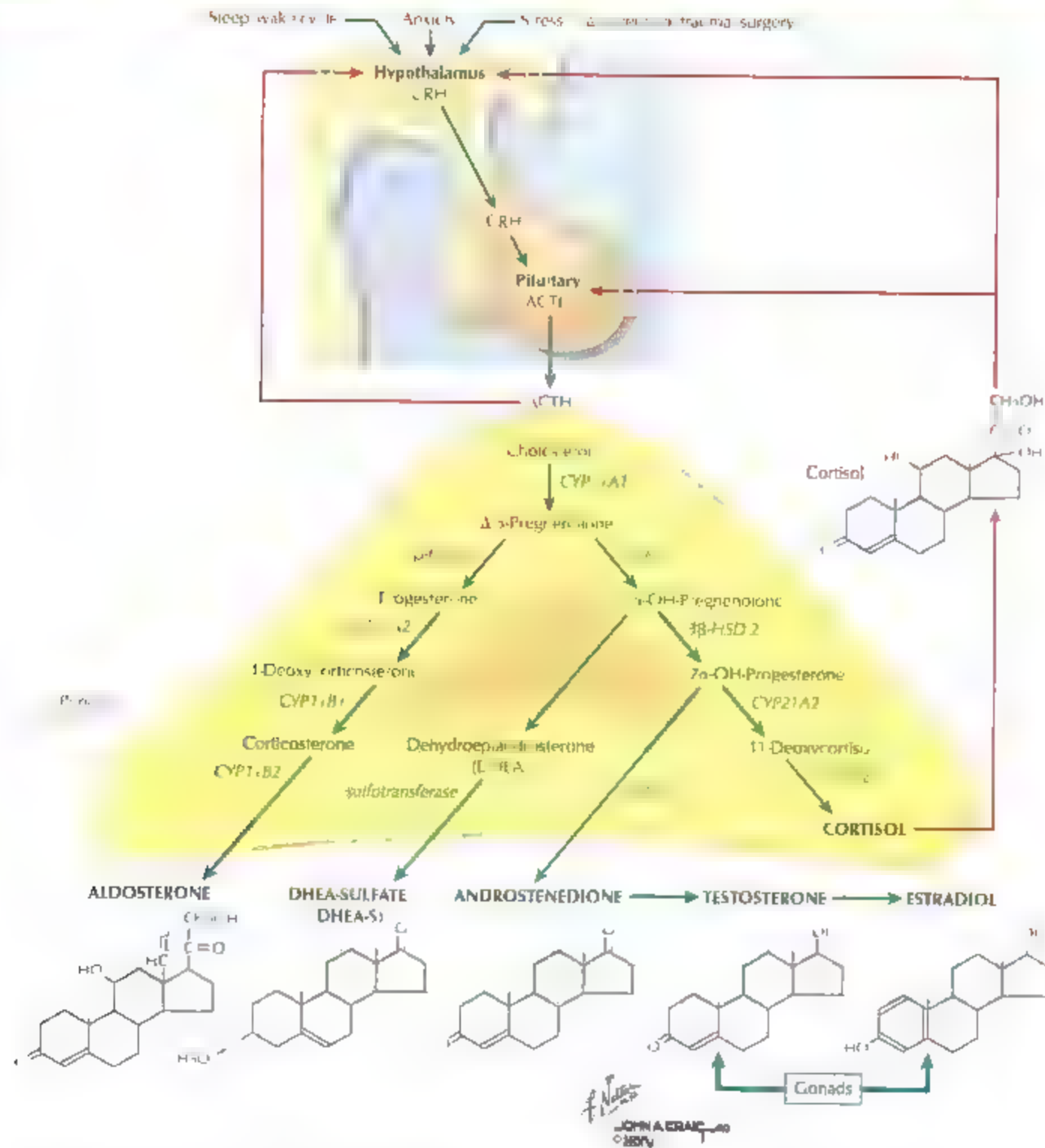


FIGURE 8.13 ADRENAL CORTICAL HORMONES

The adrenal cortex synthesizes and secretes glucocorticoid hormones (e.g., cortisol), mineralocorticoid hormones (e.g., aldosterone), and androgens (e.g., DHEA, androstenedione). Small amounts of androgens, testosterone and estradiol, are derived from the adrenal cortex, but the gonads are their primary source. All the adrenal cortical hormones are derived from cholesterol. Cortisol secretion is under the control of adrenocorticotropic hormone (ACTH), which is secreted from the anterior pituitary in response to corticotropin-releasing hormone. ACTH also stimulates the synthesis of adrenal androgens. ACTH is not the primary regulator of aldosterone secretion (see Figure 8.14). Aldosterone secretion is primarily regulated by the renin-angiotensin-aldosterone system (RAAS).

The adrenal cortex also synthesizes and secretes androgens. Androgens are steroid hormones that are primarily secreted by the testes in males and the ovaries in females. In the adrenal cortex, androgens are synthesized from cholesterol and are secreted as DHEA, androstenedione, and testosterone. Androgens play a role in the development of secondary sexual characteristics and in the maintenance of bone density. The synthesis of androgens in the adrenal cortex is regulated by ACTH.

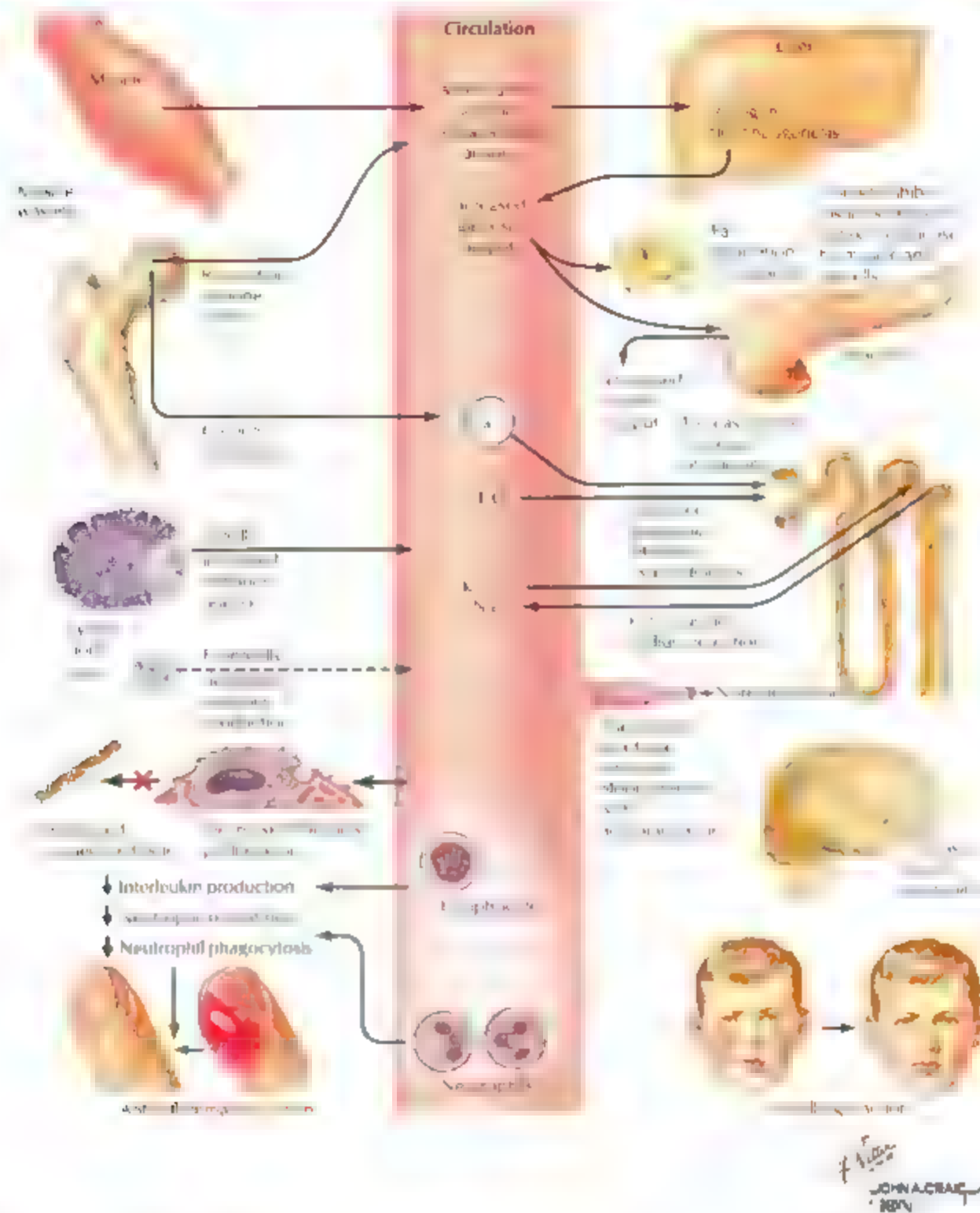


FIGURE B 14 ACTIONS OF CORTISOL

Cortisol has many effects on the body. It increases the breakdown of muscle protein and the release of amino acids into the circulation. It also increases the breakdown of fat and the release of free fatty acids into the circulation. Cortisol also increases the breakdown of glycogen in the liver and the release of glucose into the circulation. Cortisol also has effects on the immune system, the endocrine system, and metabolism.

Cortisol also has effects on the stress response, leading to increased heart rate and blood pressure. It also increases energy expenditure. Cortisol is a powerful hormone with many effects on the body.

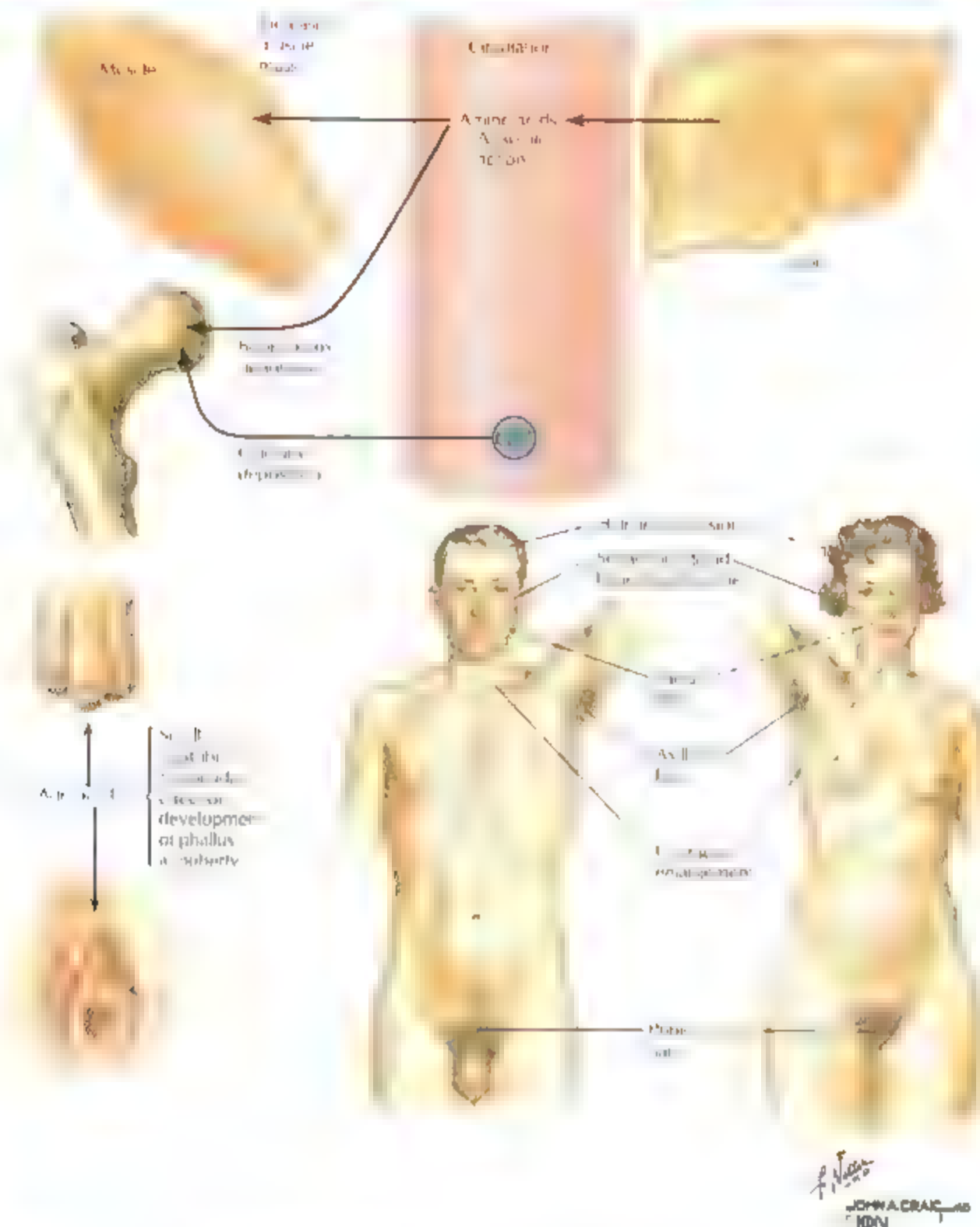


FIGURE 8.15 ACTIONS OF ADRENAL ANDROGENS

The adrenal androgens, Δ^4 -androstenedione and Δ^5 -androstenedione, do not have major effects in males, where the androgens testosterone predominate. In females, the adrenal glands are the primary source of circulating androgens. These adrenal androgens are responsible for the development of the phallus and axillary hair. In both sexes, adrenal androgens play a role in the development of the external genitalia and other secondary sexual characteristics.

As the androgens Δ^4 -androstenedione and Δ^5 -androstenedione are converted to testosterone, they also have effects on the development of the external genitalia and other secondary sexual characteristics—a process termed *adrenarche* (see Figure 8.25). The general effects of androgens are anabolic, leading to increased muscle mass and bone density. The androgens also stimulate the growth of body hair and the development of the external genitalia.

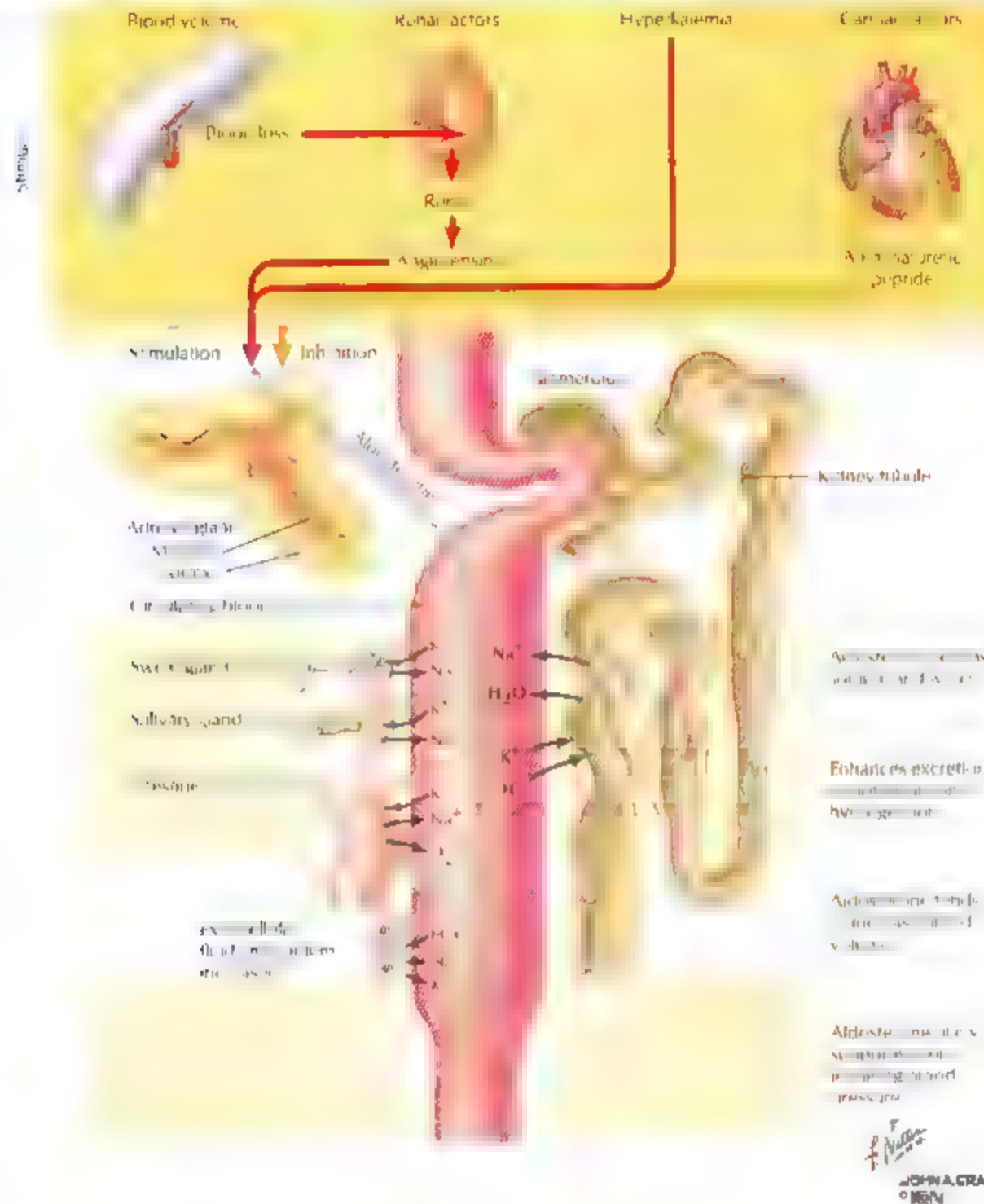


FIGURE 8.16 ACTIONS OF ALDOSTERONE

The mineralocorticoid aldosterone plays a significant role in maintaining electrolyte balance. When ECF and blood volumes are reduced (e.g., hemorrhage), aldosterone is released from the kidney, which in turn increases aldosterone levels. Aldosterone serves as a direct stimulator of aldosterone secretion by the adrenal gland. Aldosterone acts on the distal tubule and collecting duct of the kidney to increase reabsorption of Na^+ and H_2O and excretion of K^+ . This response that serves to increase ECF and blood volume. The kidney is the most important organ in this response (see Figures 8.15 and

8.16). When the ECF and blood volumes are reduced, the hypothalamus releases a neurohormone, angiotensin II, which stimulates the release of aldosterone from the adrenal gland. An increase in the K^+ concentration in the ECF also stimulates aldosterone secretion by the adrenal gland. Aldosterone acts primarily on the kidney to stimulate Na^+ and H_2O reabsorption and K^+ excretion. However, aldosterone also acts on the heart to increase contractility and on the liver to increase synthesis of albumin and angiotensinogen (see Figure 8.16).

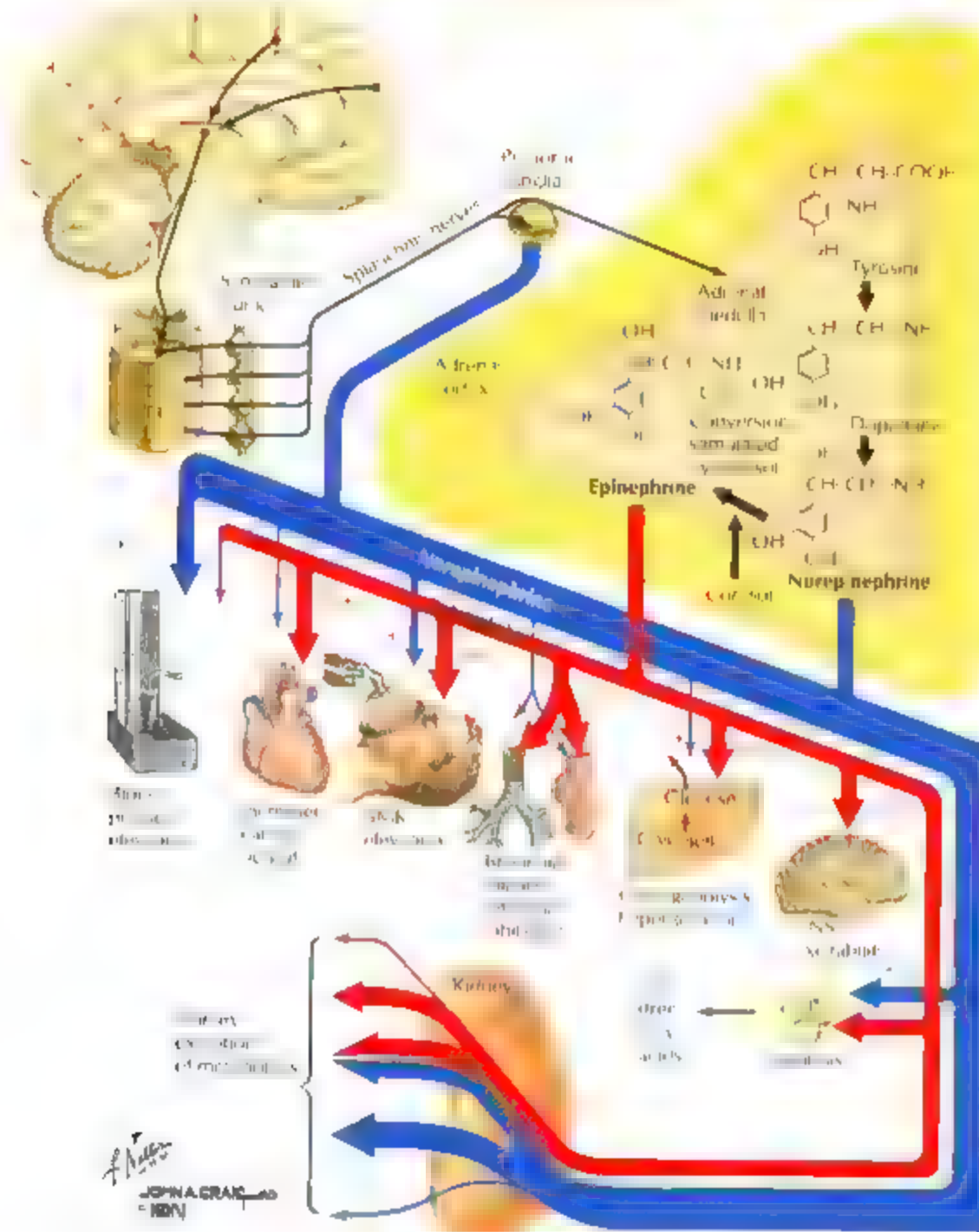


FIGURE 8.17 FUNCTION OF THE ADRENAL MEDULLA

The adrenal medulla produces epinephrine and norepinephrine. The medullary cells actually are modified sympathetic neurons. The sympathetic division of the autonomic nervous system stimulates the medulla to release epinephrine and norepinephrine into the blood.

In the adrenal medulla, epinephrine is secreted into the blood. The medullary secretions are released into the bloodstream. The relative magnitude of the secretions of epinephrine and norepinephrine is illustrated.

[illegible]



J. Perkins
MS, PhD
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FIGURE 8.19 INSULIN SECRETION

The β cell is a specialized endocrine cell that secretes insulin. It is located in the islets of Langerhans in the pancreas. The β cell is a specialized endocrine cell that secretes insulin. It is located in the islets of Langerhans in the pancreas. The β cell is a specialized endocrine cell that secretes insulin. It is located in the islets of Langerhans in the pancreas.

The β cell is a specialized endocrine cell that secretes insulin. It is located in the islets of Langerhans in the pancreas. The β cell is a specialized endocrine cell that secretes insulin. It is located in the islets of Langerhans in the pancreas. The β cell is a specialized endocrine cell that secretes insulin. It is located in the islets of Langerhans in the pancreas.

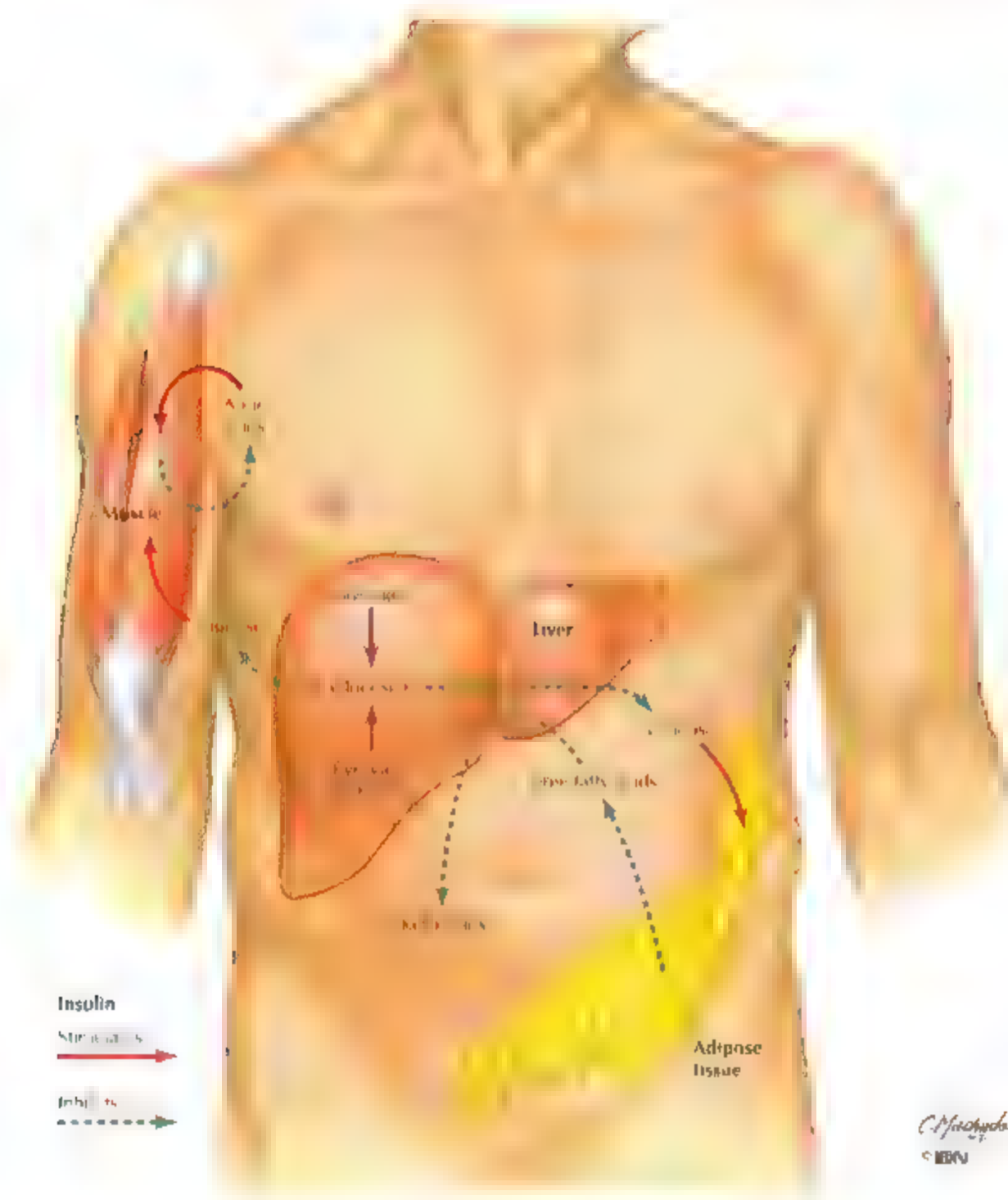


FIGURE 8.20 ACTIONS OF INSULIN

Insulin is a anabolic hormone. The main cells used by cells are muscle, liver, and adipose tissue. In muscle, insulin stimulates glucose uptake and amino acid uptake. In the liver, insulin stimulates glucose uptake and amino acid uptake. In adipose tissue, insulin stimulates fatty acid uptake and glycerol release. Insulin also inhibits the release of glucose and fatty acids from the liver and the release of glucagon from the pancreas.

Insulin also stimulates the release of fatty acids from adipose tissue. In the liver, insulin stimulates the release of fatty acids. In the pancreas, insulin stimulates the release of insulin and inhibits the release of glucagon. Insulin also stimulates the release of insulin from the pancreas.

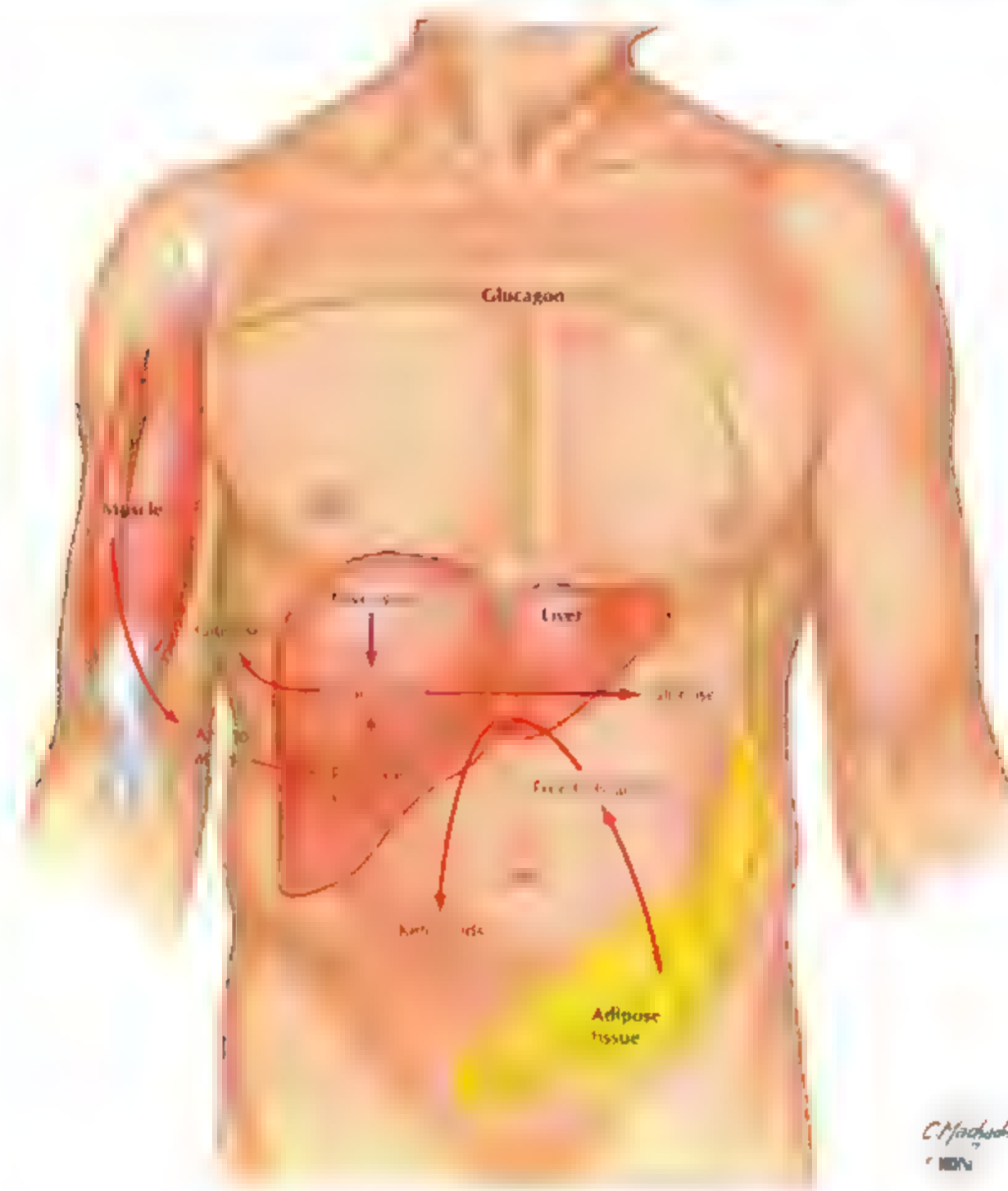


FIGURE 8.21 ACTIONS OF GLUCAGON

Glucagon is a hormone secreted by the α cells of the pancreas. It is released in response to low blood glucose levels. The main action of glucagon is to increase blood glucose levels. It does this by stimulating the liver to release glucose from glycogen stores and by stimulating the release of glucose from the muscle.

Glucagon also stimulates the release of fatty acids from adipose tissue. This is because fatty acids are a source of energy for the body. When blood glucose levels are low, the body needs to use other sources of energy. Fatty acids are a good source of energy and can be used to produce ATP.

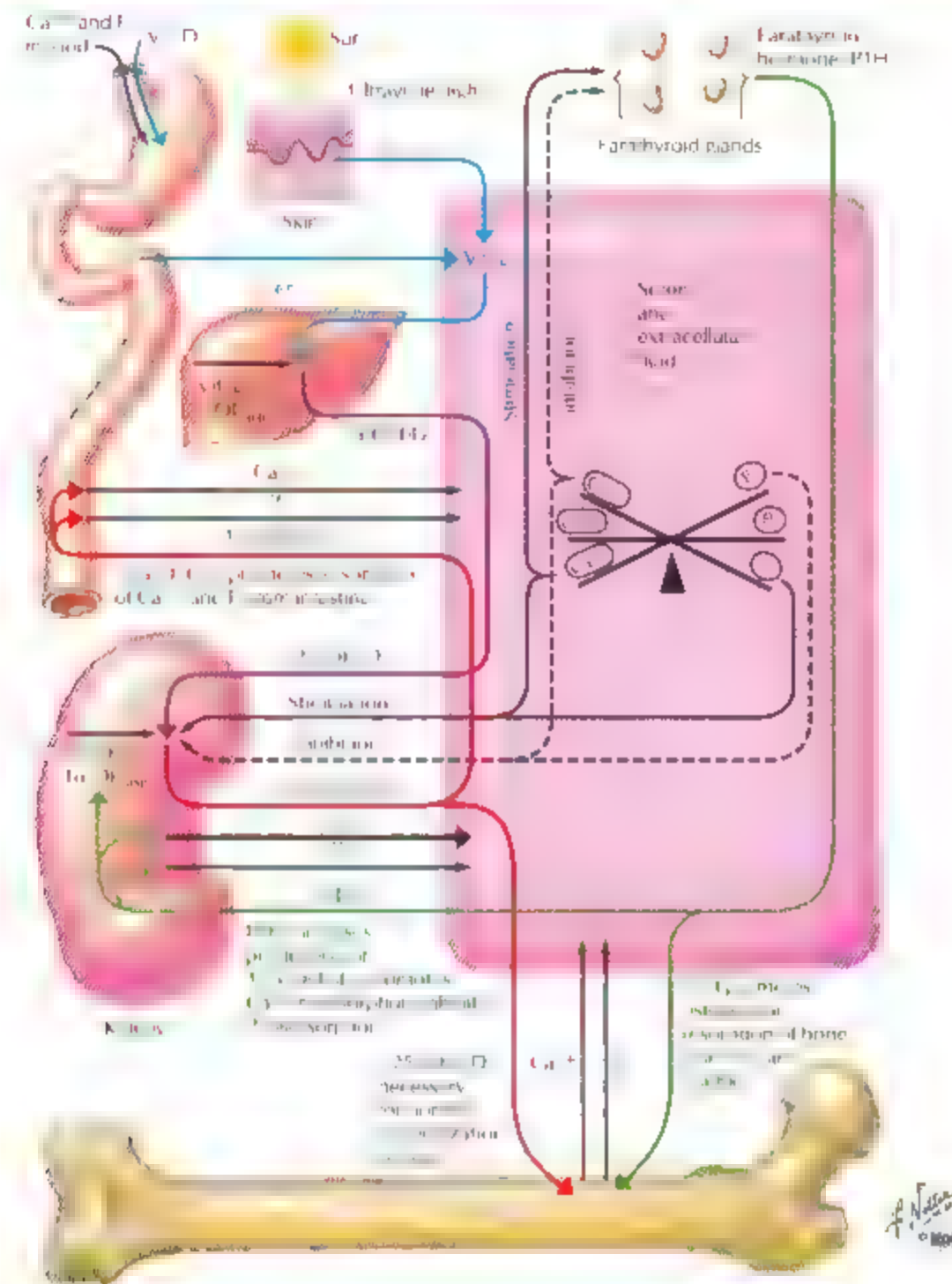


FIGURE B.22 PARATHYROID HORMONE

The parathyroid gland secretes parathyroid hormone (PTH), which acts on the kidney and bone. PTH acts on the kidney to stimulate the release of calcium (Ca²⁺) and phosphate (PO₄³⁻) into the bloodstream. PTH also acts on the bone to stimulate the release of calcium (Ca²⁺) and phosphate (PO₄³⁻) into the bloodstream. PTH is secreted by the parathyroid gland in response to low serum calcium levels. PTH acts on the kidney to stimulate the release of calcium (Ca²⁺) and phosphate (PO₄³⁻) into the bloodstream. PTH also acts on the bone to stimulate the release of calcium (Ca²⁺) and phosphate (PO₄³⁻) into the bloodstream.

PTH acts on the kidney to stimulate the release of calcium (Ca²⁺) and phosphate (PO₄³⁻) into the bloodstream. PTH also acts on the bone to stimulate the release of calcium (Ca²⁺) and phosphate (PO₄³⁻) into the bloodstream. PTH is secreted by the parathyroid gland in response to low serum calcium levels. PTH acts on the kidney to stimulate the release of calcium (Ca²⁺) and phosphate (PO₄³⁻) into the bloodstream. PTH also acts on the bone to stimulate the release of calcium (Ca²⁺) and phosphate (PO₄³⁻) into the bloodstream.



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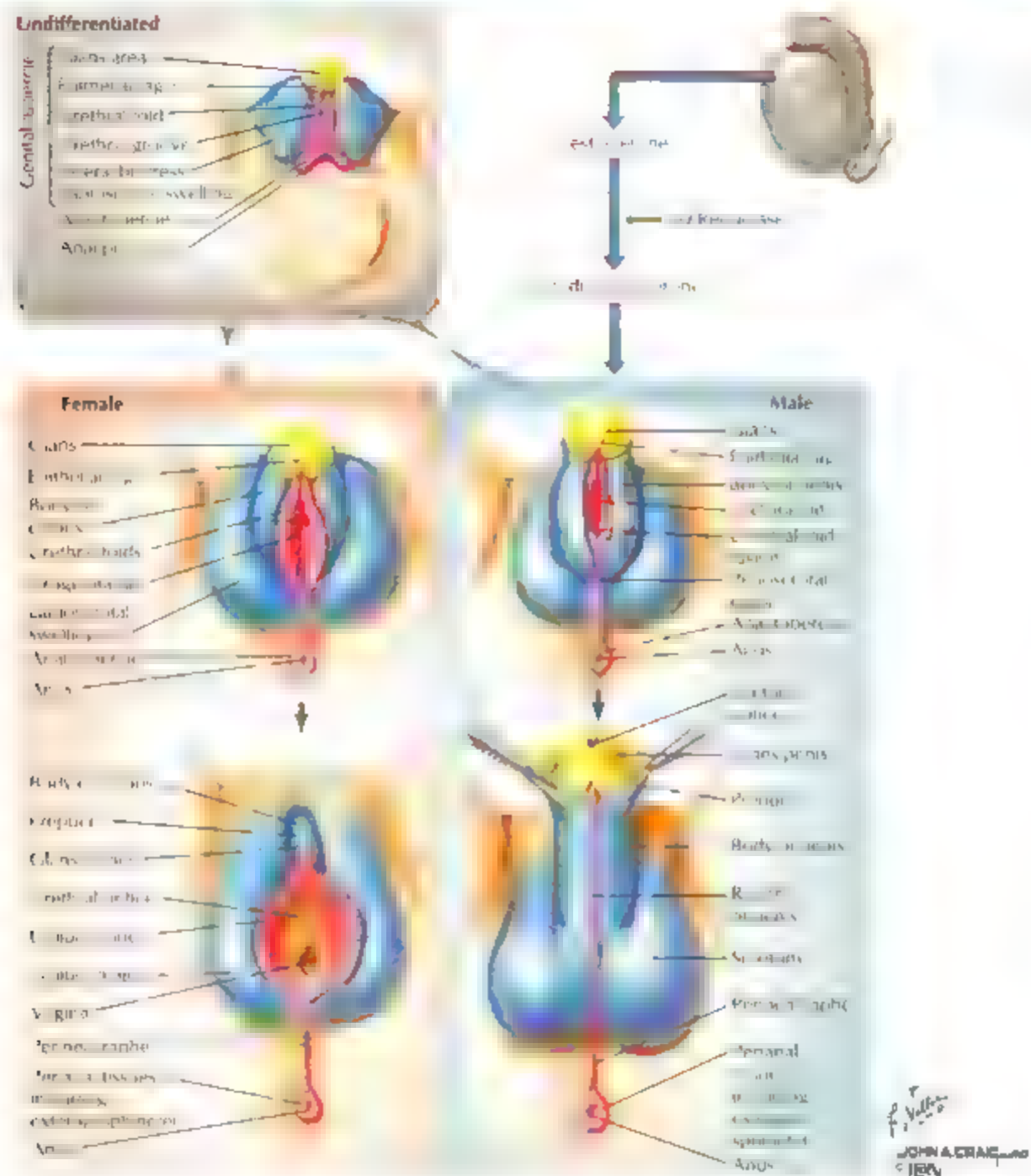


FIGURE 8.24 DIFFERENTIATION OF THE EXTERNAL GENITALIA

During embryonic development, the external genitalia (genitalia) differentiate from an undifferentiated state into female (vagina, clitoris, labia) and male (penis, scrotum, testes) external genitalia. The process is controlled by the presence or absence of the Y-chromosome and the sex of the developing fetus.

The undifferentiated genital bud is shown at the top. The female genitalia (vagina, clitoris, labia) develop from the undifferentiated state. The male genitalia (penis, scrotum, testes) develop from the undifferentiated state.

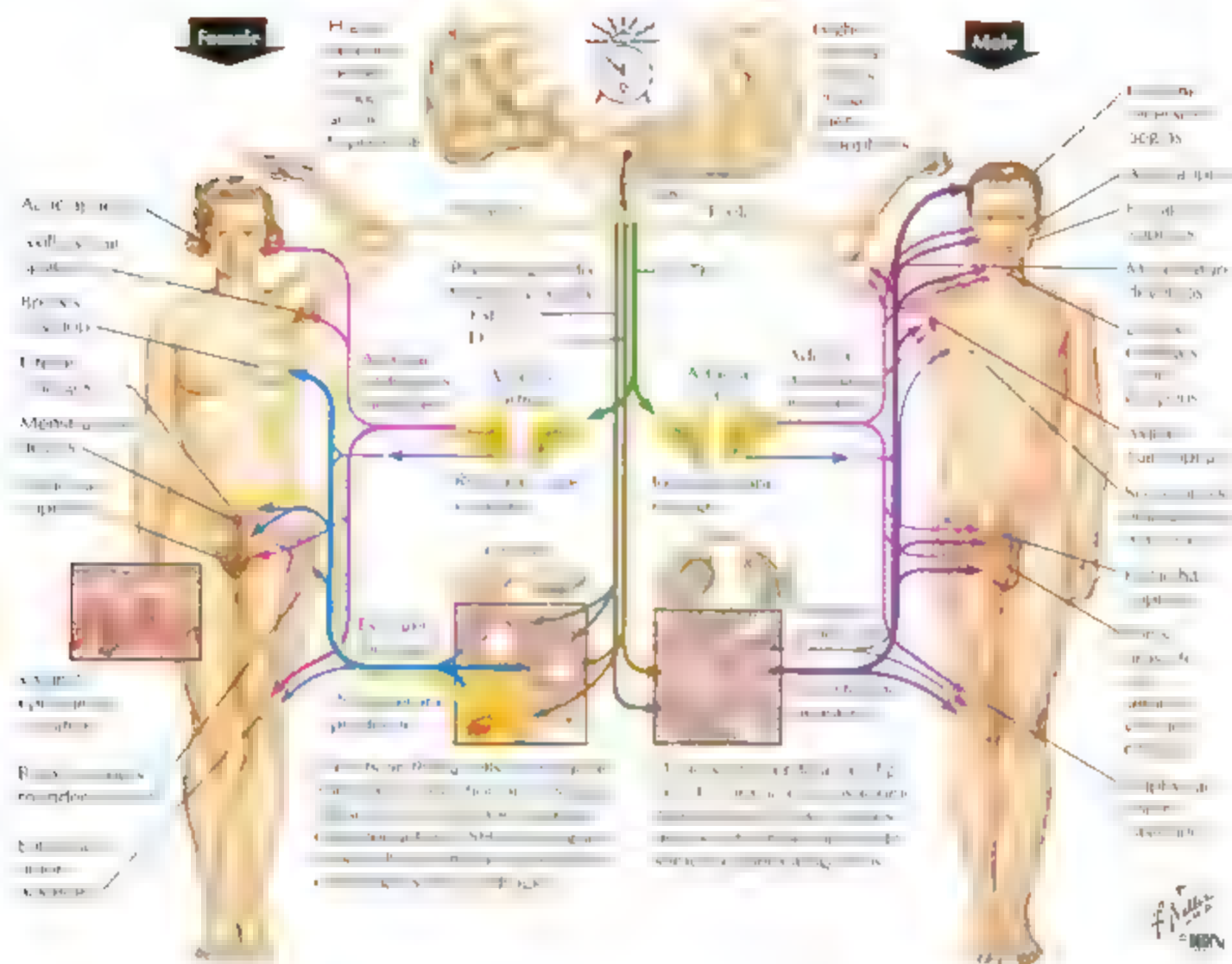
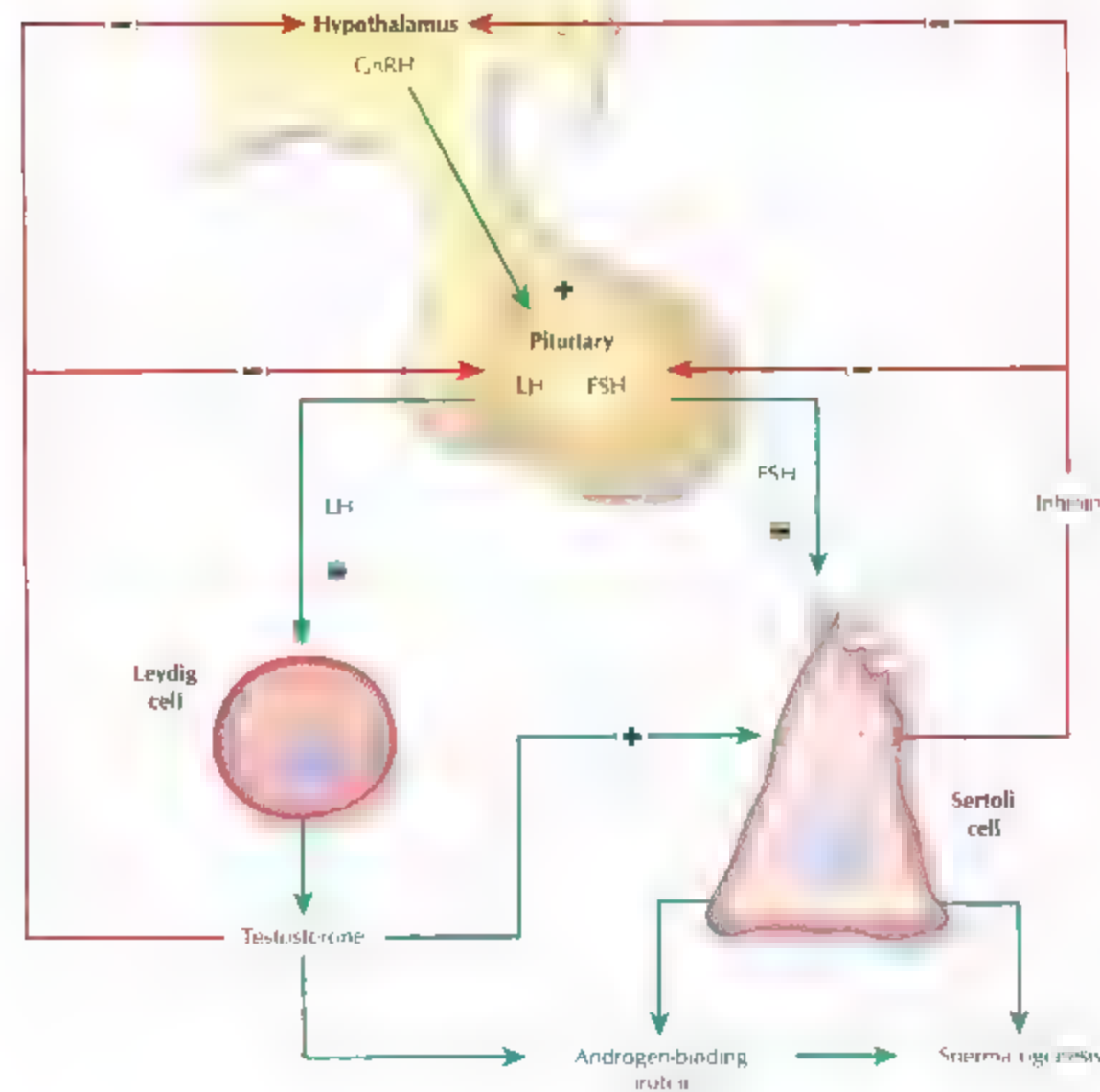


FIGURE 8.25 PUBERTY

One of the most important changes during puberty is the development of the reproductive system. In females, the ovaries begin to produce estrogen, which stimulates the growth of the uterus and vagina. In males, the testes begin to produce testosterone, which stimulates the growth of the penis and the production of sperm. The hypothalamus and pituitary gland play a key role in regulating these changes by releasing hormones that stimulate the reproductive glands.

The hypothalamus releases GnRH, which stimulates the pituitary to release LH and FSH. LH stimulates the ovaries to produce estrogen, while FSH stimulates the testes to produce testosterone. These hormones then act on the reproductive organs to promote their development and function. Additionally, these hormones influence the growth of secondary sexual characteristics, such as breast development in females and facial hair in males.



J Perkins
MS, MFA

FIGURE 8.26 CONTROL OF TESTICULAR FUNCTION

The testes are under control of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) and their secretion is itself under hypothalamic control. The gonadotropin-releasing hormone (GnRH) from the hypothalamus stimulates the pituitary to release LH and FSH, which in turn stimulate the production of testosterone by the Leydig cells and the production of androgen-binding protein by the Sertoli cells.

Testosterone stimulates testosterone in the seminiferous tubules, which in turn stimulates spermatogenesis. Testosterone provides negative feedback inhibition on LH release, whereas inhibin produced by the Sertoli cells provides negative feedback inhibition of FSH secretion.

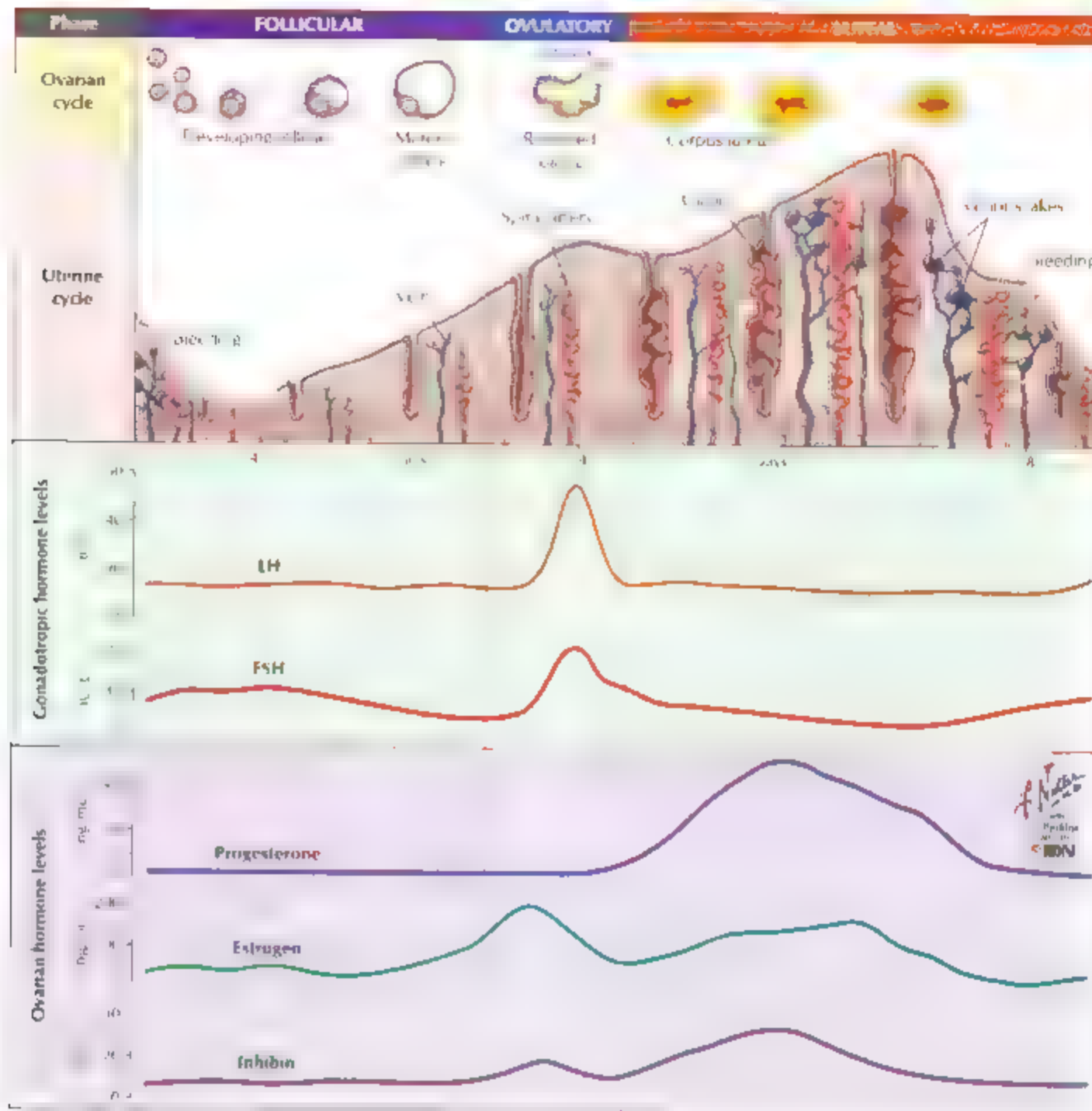
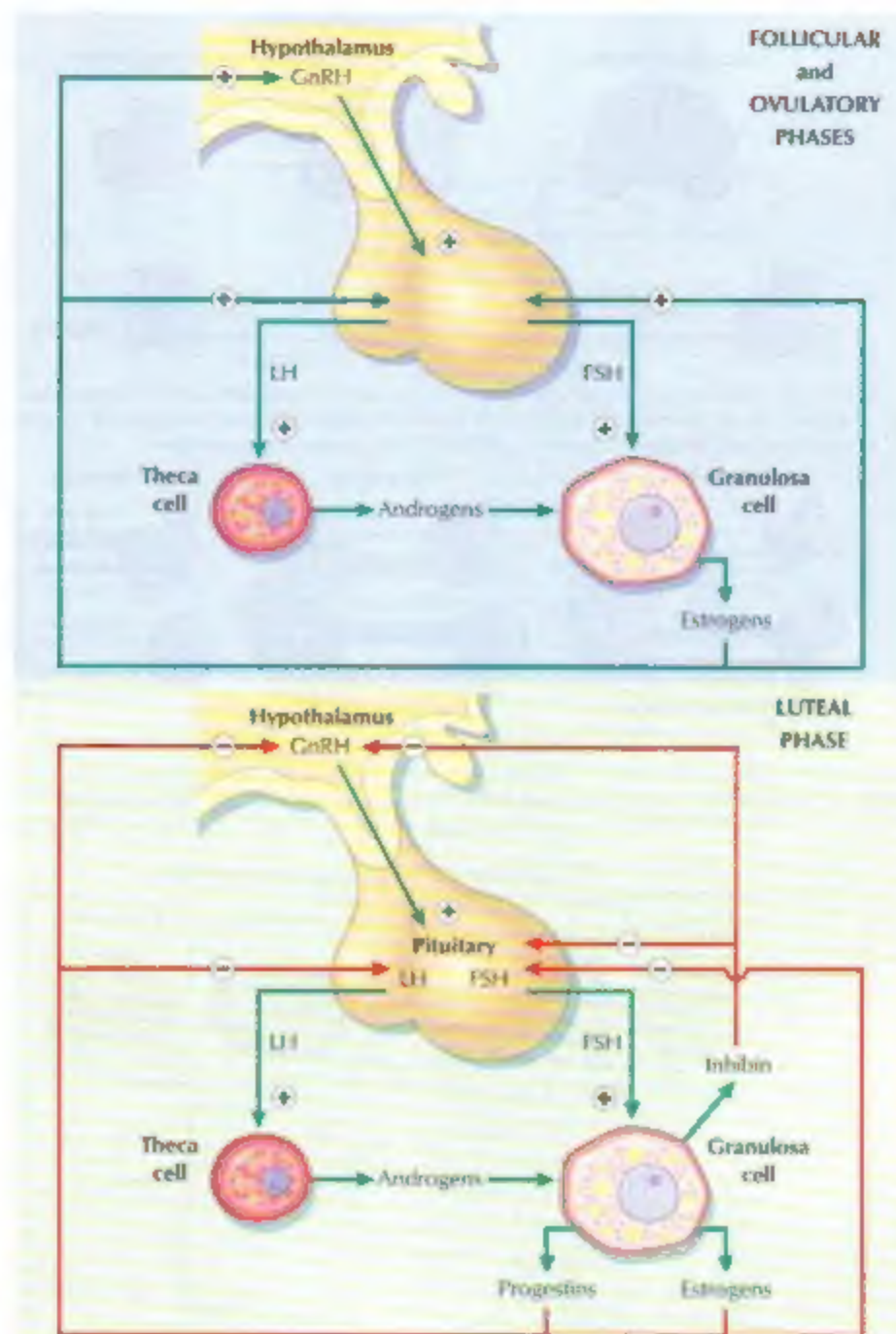


FIGURE B.27 MENSTRUAL CYCLE

The menstrual cycle is divided into two phases: follicular and ovulatory. The follicular phase begins with the growth of follicles in the ovary, which are stimulated by FSH. This is followed by ovulation, the release of an egg from the ovary. The ovulatory phase is characterized by a surge in LH and FSH, which triggers ovulation. The uterine cycle is also divided into two phases: the proliferative phase, during which the uterine lining grows, and the menstrual phase, during which the lining is shed. The menstrual cycle is regulated by a complex system of hormones, including FSH, LH, progesterone, and estrone.

Following ovulation, the follicle becomes the corpus luteum, which secretes progesterone and estrone. The corpus luteum degenerates after about 14 days, and the cycle begins again. The menstrual cycle is a complex process that involves the coordination of many different hormones and organs. The menstrual cycle is a sign of a healthy reproductive system, and it is important to understand the normal range of variation for each individual.

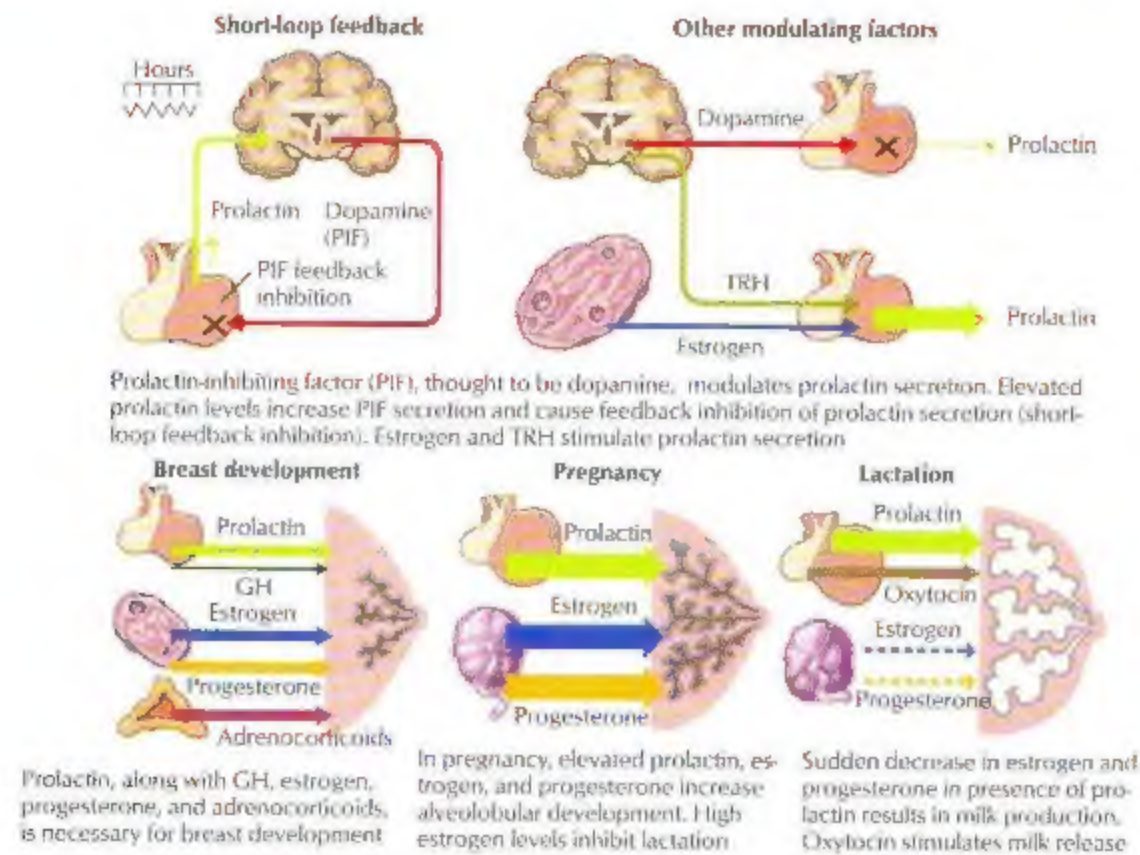


J. Perkins
MS, MTA
IBN

FIGURE 8.28 HORMONAL REGULATION OF THE MENSTRUAL CYCLE

Upper panel: During the follicular phase, the granulosa cells in a selected follicle proliferate and produce estradiol in response to follicle-stimulating hormone (FSH). At the same time, luteinizing hormone (LH) stimulates the theca cells to produce androgens. The androgens produced by the theca cells diffuse into the granulosa cells, where they are converted to estradiol. This leads to a large increase in estradiol production. The rising levels of estradiol and, to a lesser degree, progesterone (e.g., progesterone), feed back on both the hypothalamus and pituitary to stimulate (i.e., positive feed back)

a surge in GnRH secretion followed by peaks in LH and FSH secretion, which then induce ovulation. *Lower panel:* Following ovulation, the remaining follicular cells transform into the corpus luteum in response to LH and produce large amounts of progesterone and estradiol. During this luteal phase, the granulosa cells also produce inhibin. Together, progesterone, estradiol, and inhibin feed back on the pituitary to suppress LH and FSH secretion. In the absence of fertilization of the released egg, the corpus luteum regresses and menses begins.



Variations in prolactin levels by age or condition

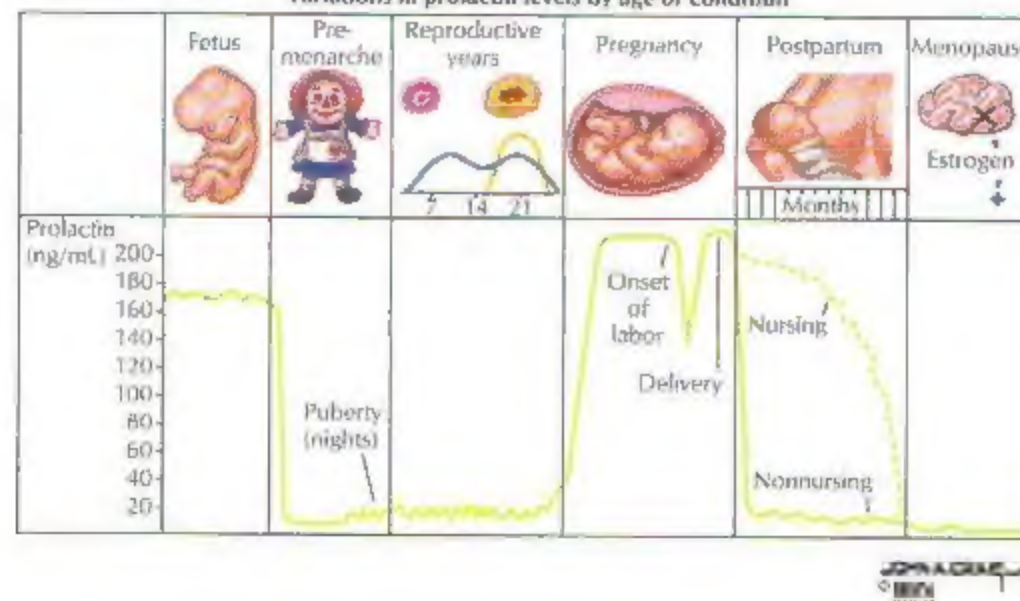


FIGURE 8.29 LACTATION

The role of prolactin in breast development, pregnancy, and lactation is summarized in this figure. Although prolactin is under dual hypothalamic control, it is unique because its secretion is under the

inhibitory control of dopamine (PIF). Abbreviations: GH, Growth hormone.

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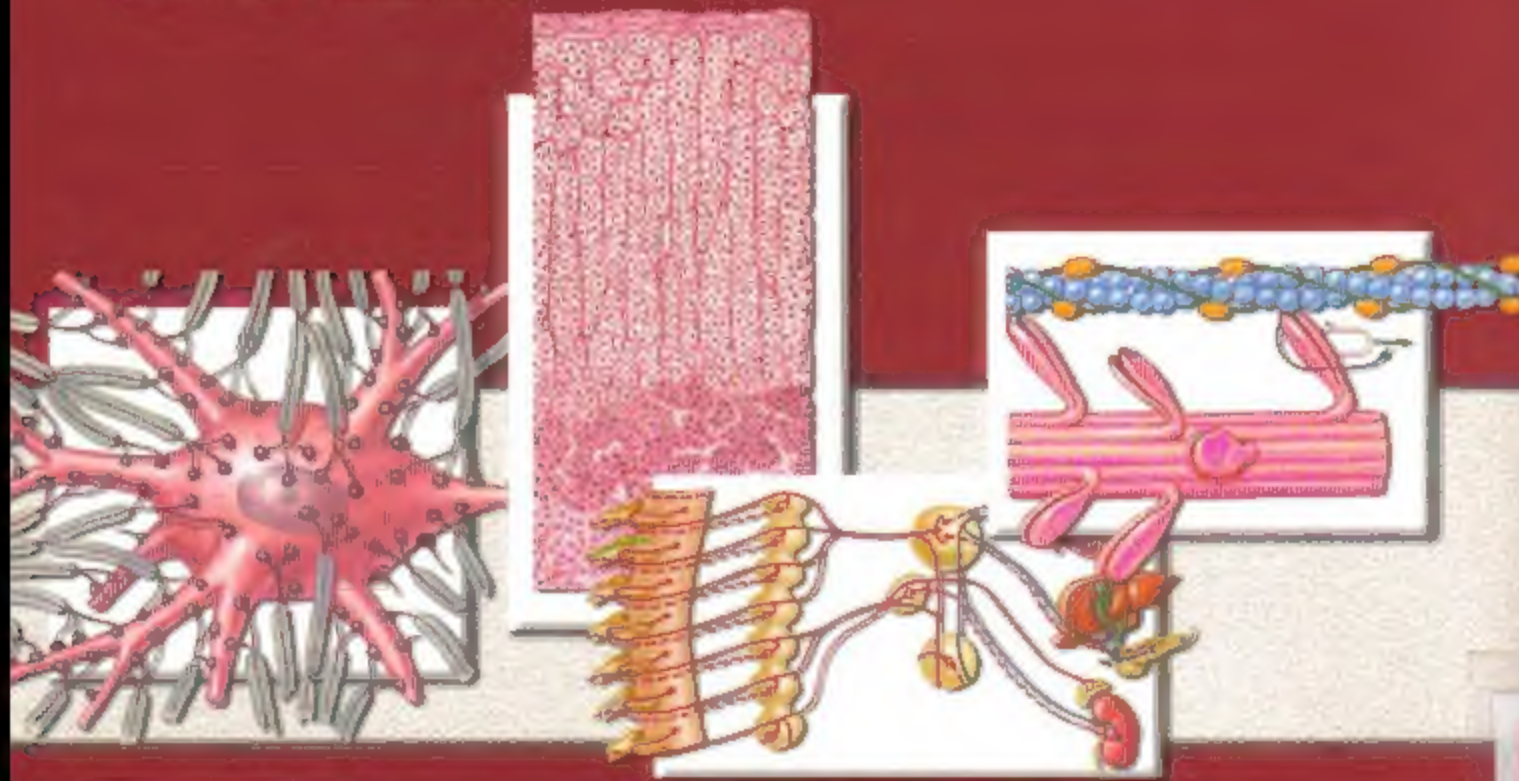
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About the Authors

John T. Hansen, Ph.D., is Professor and Associate Chair for Education in Neurobiology and Anatomy, Associate Dean for Admissions, and Director of Curriculum Development in the Offices of Medical Education at the University of Rochester School of Medicine and Dentistry. Dr. Hansen served as Chair of the Department of Neurobiology and Anatomy before becoming Associate Dean. Dr. Hansen is the recipient of numerous teaching awards from students at three different medical schools. In 1999, he was the recipient of The Alpha Omega Alpha Robert J. Glaser Distinguished Teacher Award given annually by the Association of American Medical Colleges to nationally recognized medical educators. Dr. Hansen's investigative career encompasses research of the peripheral chemoreceptor system, paraneurons, and neural plasticity and inflammation. He is author of *Essential Anatomy Dissector* and editor on the CD-ROM *Netter Presenter Human Anatomy Collection*.

Bruce M. Koeppen, M.D., Ph.D., is Professor of Medicine and Physiology and Dean for Academic Affairs and Education at the University of Connecticut School of Medicine. Dr. Koeppen is the recipient of numerous teaching awards from the students at the University of Connecticut Schools of Medicine and Dental Medicine. In 1995, he was the recipient of the Arthur C. Guyton Teaching Award from the American Society of Physiology, and he was the 1998 recipient of The Alpha Omega Alpha Robert J. Glaser Distinguished Teacher Award given annually by the Association of American Medical Colleges to nationally recognized medical educators. Dr. Koeppen's investigative career encompasses research in renal physiology and, more recently, medical education. He is coauthor of the textbook *Renal Physiology*, contributing author to *Principles of Physiology*, and contributing author and editor of *Berne and Levy's Textbook of Physiology*.